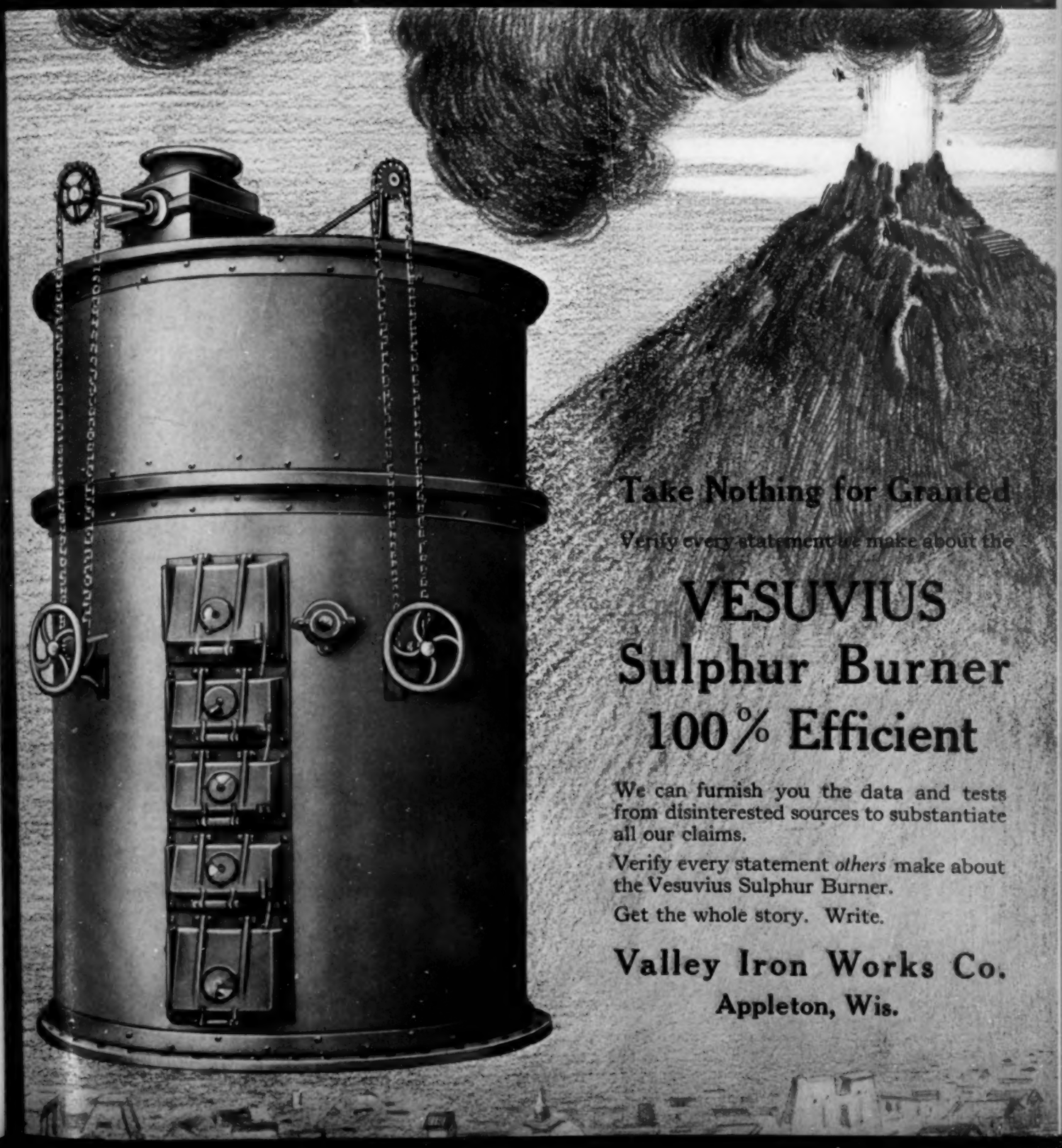
Metallurgical & Chemical Engineering

Volume XIV, Number 2 January 15, 1916 McGraw Publishing Co., Inc.



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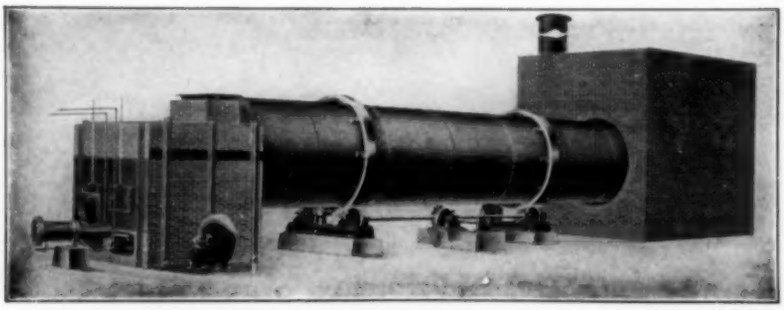

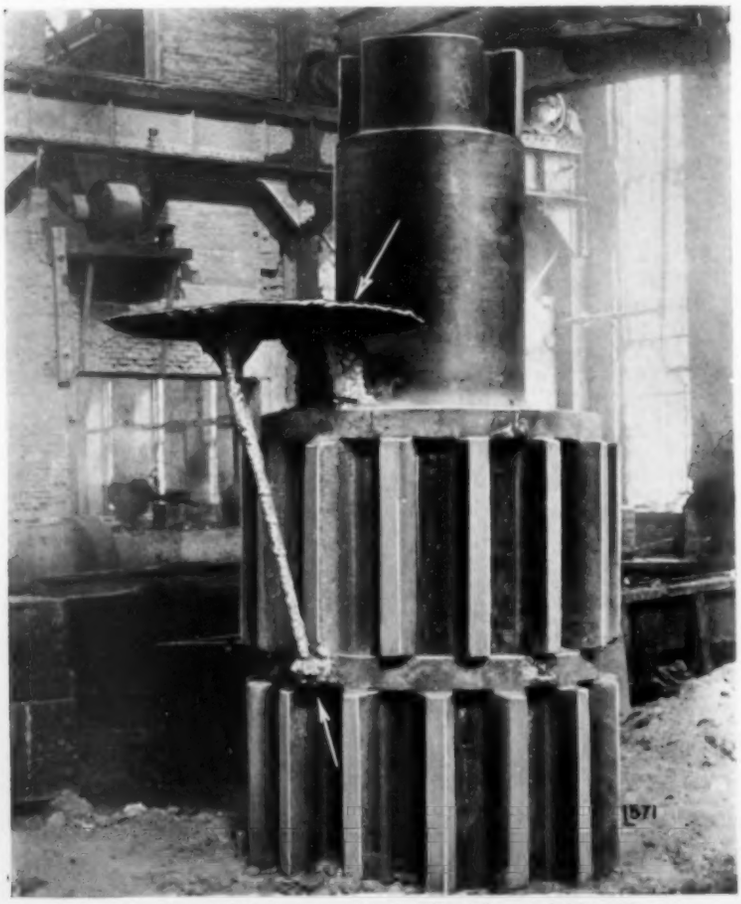

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Metallurgical and Chemical Engineering

A Consolidation of
ELECTROCHEMICAL AND METALLURGICAL INDUSTRY and IRON AND STEEL MAGAZINE

Vol. XIV NEW YORK, JANUARY 15, 1916 No. 2

PUBLISHED SEMI-MONTHLY ON THE FIRST AND FIFTEENTH OF EACH MONTH BY THE

McGRAW PUBLISHING COMPANY, INC.

JAMES H. McGRAW, President.
A. E. CLIFFORD, Secretary. JOHN T. DEMOTT, Treasurer

239 West 39th St., New York.

TELEPHONE, 4700 BRYANT. CABLE ADDRESS, METCHAM, NEW YORK.

ROCKY MOUNTAIN OFFICE.....421 Boston Bldg., Denver, Col.
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J. M. MUIR, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $3.00; all other countries, $4.00.

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Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

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Industrial Conditions After the War

A rare, a magnificent, opportunity is afforded students of political economy, to answer the great question, what will be the economic and financial conditions in the countries of the world after the war. It is a problem to which many are addressing themselves. Our captains of industry have been addressing themselves to it, not with the cocksureness of the type of political economist with which we are all more or less familiar, but rather in the mood of sounding a note of warning. That, in particular, was the attitude of Chairman Gary of the United States Steel Corporation when, apropos of nothing in particular but the conditions and possibilities as he saw them, he gave a long statement to the public on Jan. 8. He does not attempt to solve the problem, but he points out that there are grave possibilities awaiting us, and emphasizes the point that present industrial conditions are absolutely no criterion as to conditions that will prevail after the war.

It is an interesting fact that in nearly all of the many utterances on "After the war—What?" there is a strong appeal that the Government should raise a wall against "dumping." The unanimity and pointedness of the proposal, coming from so many quarters, suggests not so much certainty of thought as uncertainty, in that an anti-dumping arrangement must prove advantageous in one set of conditions, and cannot be harmful should a diametrically opposite set of conditions prevail. It is not necessary, in other words, to prove that the remedy is needed in order to advocate that it be provided. The conclusion can be reached without arranging in advance one single set of arguments leading up to it.

It is elementary, in the dealings between nations, that if one finds itself with more money or credit than others, it tends to spend the preponderance with the others. The war is rapidly increasing our preponderance. Apparently there are many who go no farther than to assume that the adjustment will be in merchandise. Others, who recognize that adjustment can also be made by the flow of capital instead of merchandise, express grave fears that such a flow of capital out of the country will be injurious. In the economic history of the United States the merchandise trade balance was almost invariably against us until 1876, and thereafter, until 1898, the favorable balances were relatively small. For a part of the time the American merchant marine earned some money, to that extent offsetting merchandise imports. During much of the time capital was flowing into the country, and in recent years it has been necessary for us to pay annually hundreds of millions of dollars return upon this capital. This has been done by our exporting more mer-

chandise than we imported. We have prospered with the borrowed money, and have been well able to pay for its use.

In the normal development of any nation such as ours there should be such a period of borrowing, for development purposes, but it seems natural that there should be a time limit to this period. The tenant should not always be a tenant, sending a portion of the fruits annually to the lord of the manor. The war tends to change our position from that of a borrowing to that of a lending nation. The real question is whether the time is ripe for such a change, whether our internal development has proceeded far enough that we do not need the extra capital that has come and is still coming to us.

Political economists recognize a factor known as "the disinclination of capital to emigrate." It is difficult even when all the conditions are known to set a value for the factor, but it exists. The capital will not be drawn from this country unless better returns are promised abroad, and that brings us in substance to the important question what will be the value of goods in different countries. Of course, many other important matters enter, but the flow of merchandise, subject to tariffs, either straight or anti-dumping, hinges upon their relative values. Relatively low-commodity values in foreign countries will exert two influences, to move the commodities to this country, and to disincline our capital to move to those countries. In the event of commodities abroad proving to be cheap, and of their importation being retarded by tariffs, our capital will tend to remain with us. Then, however, comes the more serious question what we shall do with the capital, whether we shall invest it wisely or spend it riotously. Can we spare capital, in view of our own development needs, but if we do retain it shall we use it wisely?

Science and Engineering

Dr. John A. Brashear's charming and sympathetic personality is finely displayed in his presidential address presented before the American Society of Mechanical Engineers last month. He spoke of engineering achievements of centuries long ago—of the pyramid of Cheops and the via Appia which was in perfect repair nearly six hundred years after it was finished. "I have always had the conviction that we give too little thought to the pioneers in any line of research and I have often bowed my head in reverence to those who, with the most limited means and equipment, by patient, persistent plodding, wrested the secrets of nature from their entanglement."

But the principal subject of Dr. Brashear's address was the relation between science and engineering. "Where shall we draw the line between pure and applied science? For myself, I have been unable to find aught but a hazy line of demarkation." When the velocity of the propagation of light waves was determined by scientific reasoning and experimentation of the most refined nature, the process of solving the problem remained for a long time in the domain of the exact sciences as a masterpiece of the human mind. "But who dreamed to what utilitarian purpose these light waves would be made subservient? The genius of a Michelson carried them into the workshop, thence to the International Bureau of Weights and Measures at Sevres, and gave us a value for the international meter in terms of light waves that will remain absolutely unalterable as long as this old world moves in the lumeniferous ether of the universe." "Getting nearer the utilitarian service of the scientific study of light waves, Dr. Anderson of Johns Hopkins has utilized them in making screws of hitherto unheard-of accuracy." And when in railway shops nuts made by some firms would not screw on bolts made by others, the problem at first baffled the ability of the most prominent manufacturers of tools of precision in the country, but it was solved through the co-operation of a professor of astronomy. And the development of instruments for mechanical measurements to the highest state of precision has been a mighty factor in the development of interchangeable machinery.

And this utilitarian use of science in making possible the construction of accurate screws has again reacted, as it were, and enabled the scientific mechanician to produce a little optical device that rivals, if it does not surpass, the telescope—the diffraction grating. "On the plane surface of its polished plate, made accurate to one-tenth of a light wave, or within one forty-five thousandths of an inch, are ruled more than 45,000 lines between which there is no greater error than one two-millionths of an inch. With this delicate piece of apparatus, made possible first by rigorous scientific research, second by the skill of the artisan, third by a knowledge of and vigorous care to avoid temperature changes, and fourth by the accuracy of the mechanism which includes the accurate screw mentioned above, the astro-physicist has been able to tell us the composition, temperature, and distance of the stars. It is also possible for the physicist, the chemist, to tell us the purity of the material he is called to investigate; indeed, it makes itself subservient to many phases of engineering in the domain of metallurgy. And the end is not yet. Where can we draw a sharp line of demarkation between pure science and its relation to any and every form of engineering?"

Hydrolysis of Alkali Cyanide Solutions

It occasionally happens that some of the refinements in a metallurgical process are deferred for study until long after the essential features have been made commercially successful. This may be because the refinements were not early appreciated, or because they are not forced on the attention through economic necessity. In the course of time, however, incidents arise which direct attention to points that have escaped critical thought.

A case in point seems to be the recent study that has been given to the part played by hydrolysis in the consumption of cyanide in the treatment of gold ores. It has long been known, of course, that the apparent requirement of cyanide was far in excess of that indicated

by the dissolution of the precious metals. Previous study also has been given to cyanicides of various kinds, and means have been devised to minimize their effect. Nevertheless, when all the recognized causes of cyanide consumption have been considered, we are still confronted with the fact that a large item of loss remains unaccounted for. The suggestion is now made that this loss is due to hydrolysis of the alkali cyanide into caustic alkali and hydrocyanic acid, and the volatilization of the latter from the solution.

In our synopsis of current literature in this issue we give abstracts of two important papers bearing on this subject, by H. A. White and H. M. Leslie of South Africa. In our issue for Dec. 15, we reviewed Mr. Leslie's United States patents for a system of cyaniding designed to obviate the loss due to hydrolysis. All of these are deserving of the careful consideration of cyanide metallurgists. If, as Mr. Leslie believes, a loss of from 30 to 50 per cent of the cyanide used is to be ascribed to hydrolysis, and a substantial portion of this loss can be prevented, the subject is of vital importance. South Africa consumes roughly 5000 tons of cyanide per annum; the United States, 2500 tons; Canada, 1200 tons. Mexico is an uncertain quantity, but in normal times would show a large consumption. Even a small percentage saving on this combined tonnage would be an important item of economy. We invite discussion of the subject.

English in Mining Schools and Universities

The impression grows that English should constitute almost a major course in the curricula of our schools of mines. One has but to read examination papers, theses, and even business letters written by undergraduate mining students to be convinced of this need. That there is a lack of proper preparatory work in high schools there is no doubt; but the college cannot take refuge in this excuse and escape its duty to those who are graduated with baccalaureate or professional degrees, presumably as men of some cultural attainment as well as technical knowledge.

Among students there is a strange antipathy to the study of English as something non-essential and of trifling importance. This, however, makes it more imperative for the college faculty to prescribe what is best. Perhaps it points also to a need of presenting the subject in a manner appropriate to technical students, so that they will appreciate its importance and cease to regard it as a side issue of no consequence.

It should not be difficult to impress the student with the fact that his written work is his personal representative and often the sole medium by which he is judged; that the written or printed word is subject to closer scrutiny and more critical analysis than speech; and that glaring errors in composition and spelling stand out so prominently as to distract the attention of the critical reader. It is not necessary that the engineer acquire a brilliant style or fanciful diction, but his writing should be characterized by simple, precise, and logical expression.

There is a curious inconsistency in this failure of the student to appreciate the value of English. Whereas an engineer practices exact science, using instruments of accuracy and precision, he has strangely overlooked the necessity of familiarizing himself with the equally exact, precise, and accurate tools of expression. Further, as a professional man, the engineer is expected to embody culture as well as technology, and the least he can do in adorning the latter with the former is to have a good working knowledge of English.

Several years ago an official of a large company took the trouble to investigate the training and ability of a number of engineers by examining critically three hundred of their reports on mining properties. Among graduates from technical schools only, he discovered almost unbelievable ignorance of the principles of English composition; and it was only in the work of those men whose engineering training had followed a liberal arts or classical education that culture and refinement were shown in the correct use of our language. In commenting on this striking discovery, the investigator said: "If clear writing is necessarily preceded by clear thinking, then a large body of technically trained men is hopelessly lost in the fog."

We are aware that the teaching of English has been receiving more attention in mining schools during the last few years; but there is still room for improvement. The subject must receive special attention; it cannot be handled satisfactorily by the other instructors, although they can be of benefit in supporting the special work. We can imagine that difficulty arises in finding time and place for the course in a crowded curriculum, but this will have to be done until students come to college with better training. Two alternative solutions are to lengthen the course of study or make mining engineering a post-graduate course, both of which seem of doubtful propriety at the present time.

Yet it would be unfair to speak of this problem as though it concerned mining schools alone. As a matter of fact it apparently concerns with few exceptions all our higher institutions of learning. No less a competent and well-informed observer from the engineering field than Mr. Arthur D. Little, made the following pointed remarks the other day in the symposium on the university and the industry before the New York Section of the American Chemical Society (page 941 of our issue of Dec. 15, 1915): "The business man seldom has at his disposal any more potentially efficient tool than the English language, but in his hands it is a tool which is often rusty and very seldom so keen and highly tempered as to be capable of rendering its highest service. The fault of this is largely with our universities, and the remedy, so far at least as their own students are concerned, is in their hands. Our great institutions of learning are every day disgraced by the inability of their recent graduates to make a concise and convincing oral statement of a series of facts, to prepare a well-organized and adequate report, or even to write a graceful and informing letter."

Reader's Views and Comments

A Board that Receives No Pay and Provides for All Its Own Expenses

To the Editor of Metallurgical & Chemical Engineering:

SIR:—In spite of the extraordinary extent of the field now covered by governmental activities, intelligent people still remember at times that a fundamental function of a government is to provide means for repelling foreign aggression. While immense amounts of the taxpayers' money are now spent in paying employees by whose activities many citizens are benefited but remotely or not at all, we are all vitally interested in the defense of our lives and property.

With this in mind, the following statement of Dr. L. H. Baekeland (METALLURGICAL & CHEMICAL ENGINEERING, Dec. 15, 1915, page 944) is almost incredible:

"No member of the Naval Consulting Board draws any salary nor gets any remuneration from the Government.

"We all pay our traveling and hotel expenses and each member feels that if he can give his time, free of charge, to the Government, he can still better afford to pay his own expenses.

"This program is carried out so scrupulously that even the cash for the purchase of stationery and printing is furnished by members of the board, who are monthly assessed among themselves."

It is surely bad enough that the politicians whom we allow to govern us should take our money for all sorts of unnecessary expenditures without putting us to shame by letting a group of scientific men pay for the privilege of working for our defense.

Niagara Falls, N. Y. FRANCIS A. J. FITZ GERALD.

Two Instructive Accidents from Chemical Engineering Practice

To the Editor of Metallurgical & Chemical Engineering:

SIR:—The two accidents described in the following notes may be of interest to your readers. They have occurred under my observation.

A MISAPPREHENSION AS TO THE EFFECT OF CHANGING THE CENTER OF GRAVITY

A few months ago, at one of the largest chemical manufacturing concerns in the country, a peculiar accident occurred, illustrating the result of not taking into account the shifting of the center of gravity in a cylindrical vessel standing at an angle with the horizontal, while being emptied of a liquid.

In this case, a standard-gage railroad tank car, loaded with acid, was being placed upon a car float preparatory to being ferried across a stream about 1 mile wide. The tide being out, the float was several feet below the level of the tracks, and the hinged "bridge" which formed the connection from land to float stood at a considerable down-grade. As the car was being handled over this bridge, the knuckle pin of the coupler broke and the car ran away (the brakes not holding on the steep grade) and passed upon the car float, traversed its entire length, crashed through the 12-in. x 12-in. buffer timber at the end of the track, demolished the float captain's cabin and only came to rest when one of its trucks was overboard in 12 ft. of water, and with one end of the tank projecting over the end of the float.

Those in attendance discussed the possibility of the tank dropping into the water, but reasoned that since it had come to rest, if the remaining truck were securely lashed to the end of the car still on the float, it would provide counterweight sufficient to make the tank stable enough to permit the float being moved to an adjoining wharf where provision in the way of storage tanks and compressed air were available for unloading the acid from the car. This shift was made, and the unloading progressed without incident until the liquid reached a level indicated by the dotted line in Fig. 1, when, without warning, the tank suddenly tilted over the end of the float, landing end-down in 20 ft. of water, and taking the truck along with it.

Fortunately no one was injured during the affair, and after a derrick was procured, the unloading was continued by making additional holes in the end of the tank (which projected above the water) for the application of compressed air and acid piping. The tank and trucks were recovered. Only a slight amount of acid was lost.

MISJUDGING THE CAPACITY OF A CRANE

A few months ago the writer was engaged in the installation of an iron ore concentrating machine, and among other appliances had a locomotive crane whose capacity, or overturning moment, was rated by the builders at 150 ft.-tons.

One section of the apparatus weighed 6 tons, and the nearest point we could get with the crane called for a radius of lift of 24 ft., or what would amount to an overturning moment of 144 ft.-tons. As the casting in question was loaded on a flat car, we placed the crane as near as possible to the point it would occupy when landing the casting and placed the flat car back of it, so that all we would have to do would be to raise the casting from the car, swing the crane through an arc of about 180 deg., move slightly ahead, and land the casting. The crane being fitted with rail clamps, we adjusted these but did not think it worth while to place out-riggers under the frame, as the load was within the specifications.

However, much to our surprise—and regret—when the crane had swung about 90 deg., it suddenly turned over, dropping its load, which narrowly missed two workmen. Fortunately no one was injured except the craneman, who suffered a sprained ankle after jumping to the ground, and tripping on an obstruction while running to a point of safety.

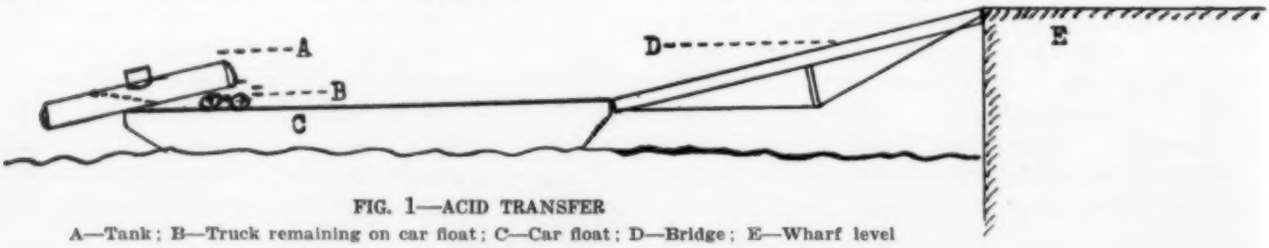


FIG. 1—ACID TRANSFER

A—Tank; B—Truck remaining on car float; C—Car float; D—Bridge; E—Wharf level

In pondering over the mishap, it suddenly occurred to us that the crane was standing on a sharp curve—22 deg.,—was swinging the load toward the center of this curve and the super-elevation of the outer rail was sufficient to shift the center of gravity from the track center toward the inner rail, thus reducing the overturning moment on that side an amount sufficient to tip the crane over.

A serious oversight in the construction of this crane was brought out in this accident, this being that the boiler was not anchored to the frame, with the result that when the crane tipped, the boiler shifted badly breaking the 2½-in. steam pipe near the boiler, and the escaping steam would undoubtedly have scalded the operator had he not been nimble enough to avoid being caught between the boiler and the levers. All owners and users of these cranes, whether engaged in bucket or actual crane service, should have this point examined at once, and suitable anchorage provided for the boilers should it be found lacking, as a capsizement is liable to occur at any time, and the results may not be as fortunate as was the case in the accident above mentioned.

Low Moor, Va. J. W. RUPERT.

Carrie Jane Everson and the Flotation Process

BY H. C. PARMELEE

When the process of concentration by flotation came into prominence in the United States several years ago the name of a woman, Carrie J. Everson, became generally known to engineers through her early contribution to that art which is now so widely practised. This remarkable woman had twice patented her ideas on flotation: first as a resident of Chicago (348,157, Aug. 4, 1886), and later from Denver (471,174, March 22, 1892). The latter patent was issued jointly to Charles B. Hebron and Carrie J. Everson.

The fact that Mrs. Everson was once a resident of Denver aroused among the engineers of that city a special interest in her identity and whereabouts. The matter was frequently a subject of casual conversation, and the suggestion was often made that a systematic search should be undertaken to ascertain whether the woman were still alive, and if so, to learn more concerning her work and the incidents that led to her discovery. The latter point was of particular moment, since a legendary account credited "Miss Everson, a Denver school teacher," with discovering the phenomena of flotation "while washing greasy ore sacks in her brother's assay office in Denver." Since no member of the mining and metallurgical fraternity in Denver could recall an assayer by the name of Everson, this story was open to doubt and offered no probable clue to the truth.

In any event, no serious effort was made to ascertain the facts until, in July, 1915, the Colorado Scientific Society appointed a committee for that purpose, consisting of George E. Collins, Phillip Argall and Howard C. Parmelee. The society's object was twofold: first, to determine beyond question the woman's part in the patented discovery, and second, to consider the advisability of proposing some form of memorial in her honor. One of the first results of the committee's work was the discovery that Mrs. Everson died at San Anselmo, Cal., Nov. 3, 1914, a fact that caused keen regret that the society's search was not undertaken at an earlier date, when the results might have been of more than historical value, not only as relating to Mrs. Everson, but also to the metallurgical industry. It can be imagined, for instance, what intense interest would have been aroused by her appearance as a witness in the hotly contested suits over the validity of certain flotation patents, for Mrs. Everson was still alive and active during the time of the litigation between Minerals Separation, Ltd., and the Butte & Superior Copper Co. And it may be more than idle speculation to consider what might have been the effect of her testimony in establishing the prior state of the art as disclosed in her own patents.

Investigation by the Colorado Scientific Society

The society's committee began its investigation by endeavoring to locate the witnesses to the Denver patent, and one Thomas F. Criley, who was credited with an early attempt to introduce the process at Baker City, Ore. As a result of searching the Denver city directories for 1885 to 1915, inclusive, one of the patent witnesses was found, Mr. E. A. Fay, in whose family Mrs. Everson had at one time lived. Many interesting details were disclosed in this directory search, among which was an inconspicuous item in 1891, "Hebron-Everson Process, Room 22, 1452 Lawrence St.," which was eloquent of the hopes and ambitions of the early promoters.

From Mr. and Mrs. Fay we ascertained many interesting facts regarding Mrs. Everson, and particularly that she had removed to California about 1909, where her son, John L. Everson, was supposed to be living. While this clue was being followed the writer had what he supposed was only a casual conversation with Mr. Arthur Chapman, a special writer for the Denver *Times*, giving him the story of the Everson matter as far as it had been developed. With true newspaperman's instinct, Mr. Chapman scented a good story and prepared an elaborate article for his paper. Among other features he emphasized the fact that Mrs. Everson's present whereabouts were unknown. The story immediately attracted attention throughout the West, and as a result of it we received a number of letters from Mrs. Everson's former acquaintances, giving various bits of information. Among others came a letter from Miss Anna E. Watson, of Pueblo, Col., who had formerly worked with Mrs. Everson as a nurse in Denver, advising us that Mrs. Everson's last known address was San Anselmo, Cal. At the same time the *Rocky Mountain News* located John L. Everson at the same address. Mr. Everson was immediately communicated with and has given us practically all the information available regarding his mother's work. The following notes are based on his correspondence.

Biographical Sketch

Carrie Jane Billings was born at or near Sharon, Mass., about Aug. 27, 1842, of early Pilgrim ancestry. About 1851 she removed with her parents to Springfield, Ill., where she received her early education, "the best possible at that period." On Oct. 3, 1864, she was married to William Knight Everson, a Chicago physician. Five children were born, of whom the only survivor is the son mentioned above. Dr. Everson was very successful in his medical practice, and Mrs. Everson took a deep interest in his work, studying various branches of science and becoming proficient in chemistry.

About 1878 Dr. Everson became interested in mining ventures, and is reported to have invested $40,000 in the Golden Age Mining Co., of Brick Pomeroy fame. This echo of the past will recall to some who are familiar with the early history of mining in Colorado other incidents in the career of that illustrious promoter, Brick Pomeroy. Dr. Everson soon realized that his investment was ill-advised, and he abandoned his interest in it. Mrs. Everson, however, is reported to have hoped that something might be saved from the wreck, and began the study of mineralogy in order to

fit her for technical investigations. Her son states that he can distinctly remember seeing her work in the laboratory, grinding ore with mortar and pestle and submitting the powder to microscopical examination, using Dr. Everson's instruments.

Some time in 1879-1880 Dr. Everson took a trip to Mexico, possibly for his health, since it is known that his health failed about that time. During this absence Mrs. Everson discovered what she then termed the "chemical affinity of oils and fatty substances for mineral particles." Her method of demonstration is disclosed in the Chicago patent, reference to which has already been made in this journal. On Dr. Everson's return from Mexico the two engaged in research for the purpose of perfecting Mrs. Everson's discovery. Dr. Everson abandoned his medical practice and devoted his resources to the work, with the result that the patent was finally obtained. Efforts were made to interest mining men in the process, but with little success, and the Eversons' financial resources gradually ebbed. Finally, on Jan. 20, 1889, Dr. Everson died at Denver, and his wife was left to care for herself and young son. As a means of livelihood she took up obstetrical nursing and practised this profession for many years in Denver.

CARRIE J. EVERSON
Photograph taken shortly after her marriage in 1864

CARRIE J. EVERSON
Photograph taken when she was a nurse in Denver

At this juncture she made the acquaintance of Thomas F. Criley, who became interested in the process. He and John L. Everson went to Silver Cliff, Col., and secured the use of an abandoned, dilapidated ten-stamp mill for experimental purposes. An 800-gal. tank was constructed, with revolving paddles and an adjustable horizontal partition. The partition was made of two pieces, hinged in the middle so that the leaves could hang vertical or be raised to a horizontal position. In carrying out the test, the tank was filled with water, and after the ground ore and oil were thoroughly mixed the mass was placed in the tank. The paddles were revolved so as to agitate the mixture, and after thorough agitation the dividing partition was raised to separate the floating mineral and oil from the water and tailing. The latter was removed through a gate in the bottom of the tank. The oily concentrate was collected in iron pans and placed in the fire-box of the boiler in order to burn off the oil. Mr. Everson reports that the ore thus treated was quite coarse, over half of it larger than 40 mesh. The concentration ratio was about 4:1, but for one reason or another the general result was not successful. Mr. Criley then tried to interest people in Baker City, Ore., and Mrs. Everson went there with him for that purpose, but was not successful.

Introduction of Hebron-Everson Process

The advent of Charles B. Hebron on the scene occurred about 1891. He is reported to have been a chemist from New York, claiming to have had experience in ore concentration. It appears that he had little faith in the use of oil, but when Mrs. Everson explained that she had also made use of lamp-black and other materials to effect flotation he showed more interest. Through his instrumentality funds were secured for getting the second, or Denver, patent, which discloses the use of "charcoal, coke, lamp-black, plumbago, any sort of friable vegetable fibers—such as bark, moss, straw, cotton, wool—also sulphur (sublimed), aluminum trihydrate, hydrated lime sulphate, sodium oleate and other cheap salts of sodium, also the cheap metallic sulphates and oleates" as "buoyant materials."

Mr. Hebron secured funds for experimental work and gained the co-operation of a Mr. Pischel, of Denver, in consideration of an interest in the patent. They carried on some work in an old building in Valverde, near Denver, where Hebron set up a sluice box about 60 ft. long, 6 ft. wide and 18 in. deep. Cleats were nailed on the bottom of the box at intervals of 2 ft. to produce gentle ripples on the surface of the water running through the box. An adjustable gate at the lower end of the sluice permitted regulation of the surface disturbance due to the cleats. The mixed ore and buoyant material was gently sifted onto the surface of the water at the head of the box, and by the time it had reached the lower end the separation of mineral and gangue was complete and the two products could be collected separately.

After a few tests the process seemed to be successful, and the principals were elated at the prospect. Here, however, another touch of human nature entered into the misfortunes of the Everson process, for "Mr. Hebron and Mr. Pischel quarreled over the millions each was to make, and the whole matter was abandoned."

As far as we are able to learn, the succession of disheartening failures now caused Mrs. Everson to abandon hope of ever bringing the process to a successful issue, and she took no further active steps in that direction. In 1892 she accepted a position as visiting nurse for the Denver Flower Mission and continued in that position until 1906. At that time she was engaged on the staff of the State Industrial School for Girls, near Morrison, Col., and remained there until she removed to California in 1909. She died at San Anselmo, Nov. 3, 1914, and was buried in Mount Tamalpais Cemetery.

Inventor's Confidence Unshaken

Although Mrs. Everson apparently abandoned all hope of ever commercializing her inventions, she is reported to have been confident that some one would at some time do so. She did not learn of the success of flotation until after her patents had expired, and at that time it was too late for her to secure any advantage. Her son states that she always felt that

a combination of flotation and cyanidation would prove profitable—a prophecy that is about to be fulfilled.

In personality Mrs. Everson is described by her friends as a quiet, kindly, self-sacrificing woman who devoted her life to those less favored than the majority. All who knew her bear testimony to her sterling character and worth and her happiness in being of service to others.

The accompanying photographs show her first as a young woman, shortly after her marriage, and later as a nurse. The former was furnished by her son, and the latter by Mr. Fay. As far as we are aware, these are the only photographs extant. Mr. Everson states that his cottage at San Anselmo was destroyed by fire in December, 1910, at which time all of Mrs. Everson's patent papers, contracts and correspondence were destroyed. Enough facts have been established, however, to set at rest the rumors, legends and apocryphal stories regarding her life and work.

The question has been asked repeatedly, Why was not Mrs. Everson's work appreciated in an earlier day before the patents expired? For answer there may be several reasons. In the first place we may imagine that the process was ahead of its time as far as metallurgical necessity was concerned, and therefore was not appreciated. Again, we may easily conceive that it was passed by as "a crazy notion" that did not appeal to the practical men of the time. And finally, with all due respect to its inventor, we can readily believe that there were some who scoffed at the process because it was "discovered by a woman." On the other hand, there may be found a reason in the fact that the second patent departed from the fundamental ideas of the first, viz., the use of oil and fatty substances, and substituted lamp-black and a long list of other buoyant materials. In other words, the Hebron-Everson patent does not now seem to be as important as the original Everson patent, and it may have been a mistake to admit the innovations insisted upon by Hebron, even though they were first conceived by Mrs. Everson. However, the fact remains that Mrs. Everson stands in the position of an originator of the process of concentrating mineral by oil flotation, and while no financial advantage accrued to her from her discovery, she is generally credited with having disclosed in 1886 all the essential elements of the process as practised to-day.

The Iron and Steel Market

The slight lull that seemed to develop in the steel market in the second half of December proves to have been of no significance. In so far as it represented a holiday slackening its influence disappeared before the normal time, for the characteristic holiday lull is supposed to extend to the middle of January at least, an evidence of the holiday influence being quickly shaken off appearing in the fact that several important advances in finished steel prices occurred the first week in January. In major part, however, such quieting down in steel buying as occurred was due to the fact that the market was fully sold, indeed oversold. The mills cannot indefinitely continue to sell week by week much more material than they produce, nor can buyers indefinitely buy in such manner.

In the case of nearly all steel interests the December bookings of actual shipping orders made a new high record, the bookings being chiefly in the form of specifications against contracts, and chiefly contracts written long ago. Sometimes the passage from one calendar quarter to another effects a decided change in the rate of specifying, the contracts coming into force being at materially higher prices than those just expired. In this case, however, steel price advances have been so rapid that the current market is much higher than the level at which many contracts for the present quarter were written, and specifications this month are likely to prove very large, possibly as large as in December. Taking the mills as a whole it will not be until the second quarter of the year that they will be given much opportunity to catch up in their rolling schedules, while the outlook is that they will never catch up until consumption decreases.

Since early in December shipments of steel from the mills for direct export have been greatly curtailed, chiefly through the action of the railroads in placing embargoes until the large volume of material in cars at eastern terminals has been moved. The net effect of the embargoes has been reduced, but only slightly, in the past fortnight. During this curtailment in export shipments from mills the shipments to domestic buyers are correspondingly increased, and the material is all welcome. A still greater scarcity of steel in the domestic market is to be expected when export shipments are increased.

Chairman Gary of the United States Steel Corporation on Jan. 8 made a lengthy statement to the public, through the medium of the daily press, expressing the belief that there was great expansion and the fear that there was also great inflation. He pointed out that prosperous conditions were assured only while the war lasted, there being grave dangers thereafter, and stated that he expected the war to end sooner than most people expected. As to steel prices, they were high, but the buyers frequently caused advances themselves, and steel price advances were probably not ended.

During the first week in January the following advances in steel prices occurred: Bars, plates and shapes, $1 a ton; standard steel pipe, line pipe and oil country goods, $1 to $2 a ton; steel boiler tubes, $4 a ton; blue annealed sheets, $3 a ton; railroad and small spikes, $3 a ton; cold roll strip steel, $5 a ton; rivets, $2 a ton, and bolts and nuts, 10 per cent.

Steel ingots are being produced at the rate of 40,000,000 or 41,000,000 tons a year, and the new construction of open-hearth steel furnaces, including two cases of duplexing plants, involves an addition of between 10 and 11 per cent to the capacity. More than half the new construction will likely be completed by July 1. There appears to be new construction in finishing departments sufficient to prevent a surplus of unfinished steel. Ten blast furnaces are being built or are definitely projected, representing about one-half the raw material requirements of the additional open-hearth capacity. As pig iron has already become scarce, and both pig and scrap prices have advanced sharply in the past two months, there are possibilities that the alignment of the new construction program now being worked out will produce a definite shortage of pig iron.

The steel mills are now booking very little business in the form of open contracts for specification in future. Specific orders they will accept for such delivery as they can compass. The total of specific and contract commitments represents an average of fully six months of full production, but in some lines the commitments are much greater than in others, being greatest in rails and large steel rounds, rolled alike on rail mills, in plates and in bars, and smallest in tubular goods and wire products, which are customarily not sold far ahead. The volume of wire business on books is unprecedentedly large for the product.

The United States Steel Corporation's unfilled obligations at the close of December were reported on Jan. 10 to have been 7,805,220 tons, representing an increase of 615,731 tons during the month. The normal rated capacity for the month, in steel products for sale,

may be taken at 1,220,000 tons, so that the increase in unfilled obligations during the month was fully 50 per cent of the capacity, while the shipments were slightly in excess of rated capacity, making the bookings more than 150 per cent of the capacity. A large part of the increase in obligations, however, was doubtless in tin plate, which is sold under contract for the entire season of 1916.

Pig Iron

Pig iron has been quiet since the first of the month, as to the actual turnover, but the market is fundamentally very strong, and the sharp advances during December, averaging fully $1.50 per ton, do not seem to have left the market top heavy in any sense. The furnaces are well sold up for many months and shipments are readily taken. The market is quotable as follows: No. 2 foundry iron, delivered Philadelphia, $19.75 to $20.25; f.o.b. furnace, Buffalo, $18 to $18.50; delivered Cleveland, $18.80; f.o.b. furnace, Chicago, $18.50; f.o.b. Birmingham, $15 to $15.50; f.o.b. valley furnaces, 95c. higher delivered Pittsburgh. Bessemer, $21 to $21.50; basic, malleable and forge, $18 to $18.50; No. 2 foundry, $18.50 to $19. Several foreign producers of ferromanganese have withdrawn their contract quotation of $110, Baltimore.

Steel

The market for soft steel billets continues to be very narrow, as the regular consumers are fairly well covered by contracts, at much lower than present asking prices, about $32 to $33 for Bessemer and $35 for open-hearth, and in view of prices obtainable for finished products it is only occasionally that a buyer could afford to pay the prices asked. Sheet bars are nominally quoted at the same level as billets, with consumers covered by contracts. Ordinary forging billets are scarcely quotable, but forging or rolling billets to conform to war steel specifications are bringing $50 or more. Rods are probably within the range of $40 to $44, Pittsburgh.

Baltimore Meeting of the American Institute of Chemical Engineers

Inclement weather spoiled slightly the excursions on the first afternoon of the Baltimore meeting (the eighth annual meeting) of the American Institute of Chemical Engineers. But it could not detract from the success as a whole. There was an unusually good attendance at the first session, held on the morning of Wednesday, Jan. 12, at the Hotel Emerson, some 60 or 70 members and guests being present. Sickness, unfortunately, prevented the president, Dr. George D. Rosengarten, from being in the chair. In his stead Past President Dr. Samuel P. Sadtler of Philadelphia acted as chairman.

A cordial welcome was extended to the Institute by the Deputy Comptroller of Baltimore and the reply was made by Professor Withrow, who emphasized that the city of Baltimore had always been a center of chemical activity. The annual reports of the officers, the council, and the different committees were presented, which showed the institute to be in good financial condition and quite active through its various committees.

The professional session which followed brought two very interesting papers. The various factors which affect and influence the development of the chemical coal-products industries in this country were discussed by Mr. H. W. Jordan of the Semet-Solvay Co., with great lucidity and often with a fine, quiet humor. Dr. W. F. Rittman of the Bureau of Mines followed with a discussion of the chemical engineering problems of the cracking of petroleum, speaking with characteristic directness and impressiveness.

Mr. Jordan showed convincingly that if the United States is to have a complete industry in the manufacture of the many different products derived from coal, the following essential conditions must be fulfilled: co-operation of the American acid and alkali manufacturers with the coal-tar industry; co-operation of the American consumers with the American producers through long-term contracts to assure the American market; establishment of the industry on a peace-scale big enough to make it a fundamental factor in national defence; establishment on a profitable commercial basis of the manufacture of nitric acid, by fixation of atmospheric nitrogen; nationalization or rather internationalization of the industry to insure a balanced world market for all by-products; development of a system of twentieth century common school and technical school education, and maintenance of a rational tariff.

The paper was discussed by Messrs. Frerichs, Withrow, and Prochazka who gave reminiscences of early American achievements in the chemical coal-products industry.

Dr. Rittman, in his paper on the cracking of petroleum, said that the variables in the cracking reactions are temperature, pressure, time, concentration (mass action) and contact surface (catalysis) and that the engineering apparatus must be designed to fit these variables. The source of the oil is not of primary importance, but the desired end products are. Dr. Rittman dealt successively with the production of gas, of gasoline, and aromatic hydrocarbons, discussing in each case demand, supply, and future. Pictures and lantern slides were shown of the bureau's "Plant No. 1," in Pittsburgh, which produces 500 gal. benzol and 500 gal. toluol per day. Plant No. 2 which was started last week very successfully, seems a great improvement. Six or seven other plants are being erected or projected.

In the discussion Dr. Cushman and Dr. Frerichs asked some questions which were answered by Dr. Rittman.

At the Wednesday evening session the first paper was read by Dr. A. D. Little of Boston. This was a brilliant discussion on wood waste utilization, showing that the potential profits in utilizing this waste would be much greater than the actual profits in the present industry. When this waste is used as raw material an enormous by-product industry can be formed. The technical staff of Dr. Little's organization made a careful investigation of this problem on a large scale, over a period of eight months. They found that with a cut of fifteen billion feet of yellow pine the Southern lumber industry now wastes raw material which if utilized would yield daily 40,000 tons of paper, 3000 tons or rosin, 300,000 gal. of turpentine, 600,000 gal. of ethyl alcohol, besides fuel to meet all requirements of the industry. Dr. Little discussed the recovery of these products. This very able paper will be published in full in our next issue.

The next paper was read by Mr. W. S. Landis on the production of ammonia from cyanamid. This paper will be found published in full elsewhere in this issue (page 87).

The last paper was read by Mr. Maximilian Toch on the barium industry. Mr. Toch discussed the various barium salts and emphasized the necessity of a protective tariff.

A report of the other sessions and social functions of the convention, as well as publication in full of several of the other papers read at the meeting, must be reserved for our next issue.

The Rubber Industry—II

BY ANDREW H. KING

In my previous article I discussed some of the more important points in regard to the production of rubber, its properties, the nature of its molecule, proposed methods for its synthesis and also reviewed the various theories of vulcanization. In the following article I will outline factory practice in general.

Washing

After the arrival of crude rubber at the factory, the first operation which it undergoes is washing. While plantation rubbers are shipped washed and dried, many African, South American, and other varieties arrive at the factory in a dirty condition. African rubbers are particularly offensive. Besides certain putrefying plant juices which are usually present, sticks, stones, clay, etc., are often to be found.

The dirtier grades are best washed in a machine much resembling the beater of the paper mills. The better grades are washed directly on the rolls, with or without previous steeping in warm water. The rolls are corrugated, usually two in number, and a strong stream of water is thrown down between them during the operation. The rubber is passed through the rolls until clear and thin. Fig. 1 shows a modern three-roll washer. It differs from the usual two-roll type in the addition of an extra roll. This gives it an increased capacity which is said to be double that of the common type.

Drying

The wet sheets as they come from the wash room are dried either by vacuum dryers or by hanging in a warm room. Some companies do all their drying by vacuum, while others claim that the heat is injurious and use the older method. Sometimes both methods are used, it being the custom to hang everything strong enough to support its own weight, and vacuum dry the remainder. When hanging is resorted to, the sheets are hung in rows in a steam-heated, well ventilated room. This room must be darkened so as to retard oxidation. The temperature is ordinarily kept at 27 deg. C., but this is often found a little high for the cheaper grades of rubber. With good ventilation, drying is completed in three or four days, after which the rubber is milled, sheeted, and rolled up for compounding.

Compounding

As was stated previously, rubber has a reticular or network structure. It is this fact which makes compounding possible. Each little loop of the net holds its quota of material. Obviously the larger the volume of compound added the farther apart the rubber nuclei are pushed, and the more strain is placed on the little connecting filaments. Therefore, the stiffer and less elastic becomes the product. Primarily compounding is based on volume percentage. Therefore, the more light pigment present the harder is the article. Hard valves almost always contain considerable quantities of such fillers as fossil flour, aluminium flake, etc. By analogous reasoning we see that heavy pigments which have a small relative volume give the opposite properties. Snappy elastic articles are produced by the aid of such fillers as litharge, barytes, zinc oxide, etc.

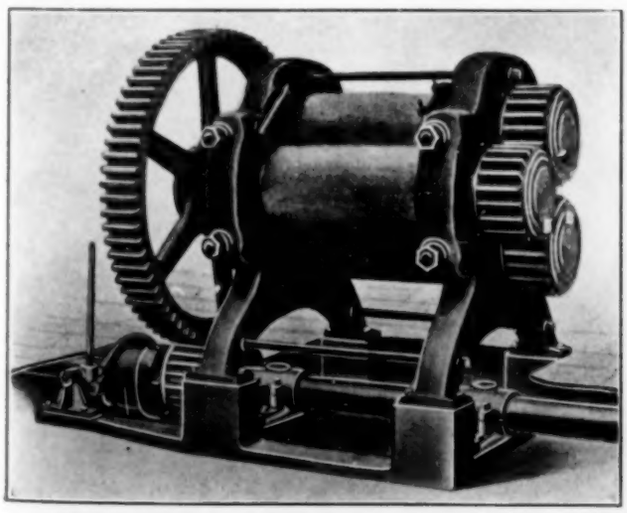


FIG. 1—THREE-ROLL WASHER

In compounding, as in the other branches of the industry, the price factor is paramount. It is the aim of the rubber chemist to always use material of just the necessary quality but no better. It is an economic sin to use Para rubber where shoddy will do just as well. The uninitiated must not get the idea that raw rubber properly vulcanized is the very best. The principal factor in determining a compound is its intended use. The degree of elasticity, toughness, strength, and resistance to abrasion must all be known before a satisfactory compound can be prepared. These properties all depend to a greater or smaller extent on the material used in compounding.

A constantly increasing variety of compounding materials finds application. There is little change, however, in the number of inorganic fillers. Very few materials are added just to fill up space. Most of them impart certain definite properties which may be used as a basis for classification, as follows:

Fillers Only.—This group embraces the various grades of rubber substitute, shoddy, ground rubber waste, and also certain inert mineral fillers such as whiting, barytes, and to a certain extent zinc oxide.

Rubber substitutes are the products derived from various oils such as rape, corn, linseed, etc., by one or the other of the following methods: First, sulphonation, the oil is boiled with sulphur; second, it is treated with sulphur chloride; or third, it is blown with air while at the boiling temperature or oxidation is effected by other means. Practically all white substitute is made by the use of sulphur chloride. Quite frequently sulphonated oils are blown. Substitute when properly prepared has a slight amount of "give," but almost no cohesiveness. It mixes easily in a compound and its purpose is simply that of a cheapener.

Shoddies will be discussed later.

Those Having a Hardening or Toughening Action.—Fossil flour, aluminium flake and other low-gravity materials act as tougheners, as explained in the foregoing. Zinc oxide, lithophone and calcined magnesia also have this property. Because of this function it is customary to find even 50 per cent or over of zinc oxide in the tread of an auto tire. Lime and litharge have a decided hardening action. It is not uncommon to find around 25 per cent litharge or 15 per cent lime in a hard valve.

Those Giving Dense, Non-Porous Mixtures.—Under this head come those materials which find application in articles which have to withstand water, steam, air, etc., under pressure. Mineral rubber, which belongs to the bitumen class, finds perhaps the greatest use in this respect. Tar and paraffine also are used.

Accelerators.—Those substances which hasten vulcanization are known as accelerators. It is quite obvious that the addition of a substance which cuts down the period of vulcanization increases a factory's output and also the profit. Their action is catalytic and they simply hasten the reaction between sulphur and rubber. Under this head come various oxides, the most important

being lime, magnesia, litharge and zinc oxide. Their relative accelerating power is shown by the order in which they are named. Lime finds considerable favor in this country, while the European preference is mostly for magnesia. Litharge is perhaps the most used of any. Lately organic accelerators have come into prominence. Ditmer claims that all organic bases having dissociation constants greater than 10^{-5} act as accelerators, regardless of constitution. To date the most important published ones are: Tetramethylenediamine, urea derivatives, carbon bisulphide addition products and piperidine.

Those Having a Softening Action.—Various oils, such as rosin and palm, are sometimes added in small quantities to soften a stiff stock for sheeting or for use on a tube machine. Heavy mineral oils, such as vaseline, are also used. It is the aim to keep away from saponifiable oils as much as possible.

Those Having a Sticky Tendency.—In building up articles such as tires, where many layers of thin sheets are used to make up a section, it is quite necessary for proper vulcanization that these layers stick tightly together. It is therefore often necessary to increase the stickiness of uncured stock by the addition of such substances as crude turpentine, tar, various pitches, etc. This factor becomes of more importance in the manufacture of frictions; i.e., fabric coated and impregnated with rubber compound.

Pigments.—The most important white pigments are lithophone and zinc oxide. In preparing a white stock it must be remembered that no lead compounds can be used since lead sulphide (black) is formed on vulcanization. The chief red pigments are: Crimson antimony sulphide, mercuric sulphide or vermilion, iron oxide and certain lakes. Antimony sulphide is much used in the production of non-blooming articles, such as auto-inner tubes of the best grade. By blooming we mean the tendency for the free sulphur to come to the surface and give a thin, dirty white scum of colloidal sulphur. Other pigments are prussian and ultramarine blue, chrome yellow, chrome green, etc.

As would be expected, compound receipts are quite valuable, and rubber companies go to considerable trouble to keep them secret. They are empirical and

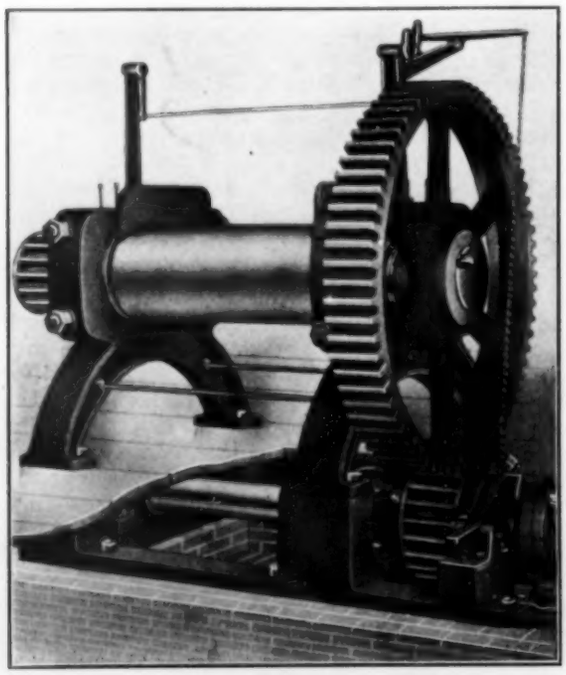


FIG. 2—SMALL-SIZE MIXING ROLLS

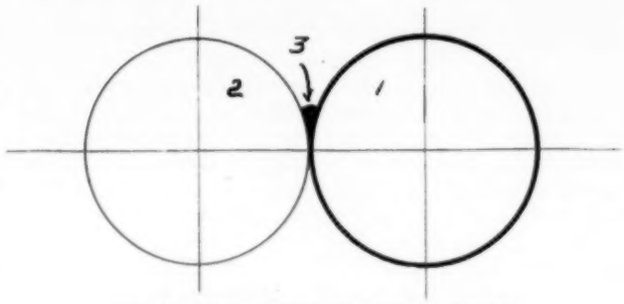


FIG. 3—OPERATION OF MIXING ROLLS

have been worked out by experiment. However, it can be said that with certain few exceptions most articles can be analyzed and the compound deduced by an experienced rubber chemist.

The correct proportions of rubber, sulphur and fillers are weighed out in the compound room. The batches are customarily of 100 lb. each. They are made up in galvanized iron pans and sent to the mixing room. It is hardly necessary to state that all mineral fillers must be ground very fine.

Mixing

In general the construction of the mixing rolls is similar to those used in washing, except that the surfaces are not corrugated. Fig. 2 is a photograph of a small set of mixing rolls. The usual factory size is from 35 to 45 in. in length, and 12 to 16 in. in diameter. The gearing is differential, the front roll running at 18 to 20 r.p.m., and the back at 20 to 25. During the operation the front one is kept slightly hotter than the back. This in conjunction with the slower speed keeps the plastic mass on the front roll. Both rolls are fitted with means of steam heating and water cooling, which are used when necessary. Set screws which operate on the front roll are used to give the desired distance between the rolls.

The first operation in mixing is to properly "break down" the rubber. The rolls are heated to a moderate temperature and the rubber passed through a number of times, until it becomes smooth and plastic but not sticky. It then covers the forward roll as is shown by 1, Fig. 3. When this condition is reached, the rolls are brought closer together, thus forming what is called the "bank." This is designated by 3 in the above-men-

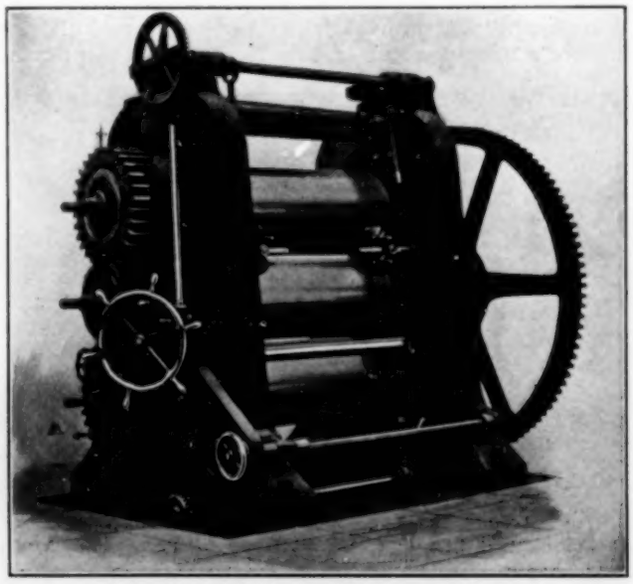


FIG. 4—24-IN. THREE-ROLL CALENDER

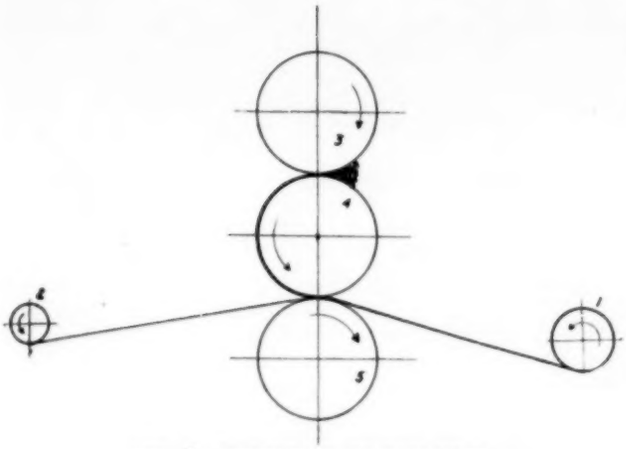


FIG. 5—OPERATION OF CALENDER

tioned diagram. Since the rubber heats up spontaneously on breaking down, it may be necessary to cool the rolls.

Shoddy is frequently broken down on separate rolls and added at this point, or the rubber and shoddy may be broken down together. Any oils or sticky material are usually added at this point. The attendant, aided by a short knife, cuts off pieces of the batch and throws these over and over on the rolls until a homogeneous mixture is effected. He then adds the powders as the mineral fillers are called. The bank acts like a third roll rotating in the opposite direction. It aids considerably in securing a good mixture.

The cutting and throwing process is repeated and finally the stock is removed, left to cool down slightly and passed through the mills, which have been opened a trifle so as to insure an even mixture. Following this the stock is sheeted for convenience.

The aim of the mixer is to have his batch well mixed before adding the mineral fillers, and to proceed as rapidly as possible from this point to avoid any overworking of the rubber lest it lose considerably in nerve.

Mixing machines are sometimes used. They consist essentially of inclosed rotating arms. The rubber is first broken down alone and the powders added. The operation is almost entirely automatic. Mixing machines find favor where considerable quantities of fine light material have to be handled. However, many old rubber men do not favor these machines, and claim that stock so mixed is apt to be deficient in nerve due to overworking or else poorly mixed.

Calendering

The object of the calender is to change the dough, or stock, as it is called, in the mixing room into sheets of even thickness, since it is from these sheets that most all rubber articles are made. Fig. 4 shows a "three-roll calender." The rolls are massive, correctly turned, and fitted with means for heating or cooling. Screws are provided for adjusting the distance between the rolls. Calenders are usually directly connected to a motor. Herringbone gears find the greatest favor, since they insure a more uniform speed. Altogether the calender is an expensive machine, and should be kept in use most of the time.

Fig. 5 illustrates the operation of the calender. The stock after being properly warmed up on a warming mill is fed in between rolls 3 and 4. By proper regulation of temperature it is caused to adhere to the middle roll, leaving the top and bottom ones clean. A strip of cloth called "liner" is taken from reel 2 and passes between the middle and lower rolls to reel 1. The sheeted rubber as it passes between these rolls is received by the liner, which carries it to reel 1 where they are wrapped up together, the liner preventing the layers of rubber from adhering. By means of knives pressed against the middle roll, the sheet may be cut into strips of any desired width.

Frictioning

Frictioning, which consists of impregnating duck or other cloth with rubber compound, is also done on the calender. The only difference is that the rolls now travel at different speeds, the bottom one revolving at about two-thirds that of the middle roll, thus causing a wiping action. The duck is first well dried by passing it over steam-heated pipes in a duck drier. It passes through the calender from reel 2 to reel 1, as described under calendering sheets. The soft dough is forced into the pores of the duck first from one side, then from another. When it is desired to give a skim coat the rolls are opened a trifle and the friction passed through just the same as in sheeting. This places a thin layer of rubber on the friction on only one side.

Rubber Cement

The making of cement is rather an important branch of the rubber industry, as will later be appreciated.

Cements are made for all sorts of purposes. Those intended for cold vulcanization contain, of course, no sulphur. For patching a very good cold curing cement is made by swelling Para rubber in a suitable solvent. However, it is customary for cements to be made from compounded stocks, the purpose deciding the character of the compound. The chief solvents are benzole (90 per cent), gasoline (70-76 deg. B.) and carbon tetrachloride. The best results are given with benzole.

The stock or rubber from which the cement is to be made is first thoroughly milled. It is then sheeted and cut into fairly small pieces. These are placed in a churn with the required amount of solvent. After some time the rubber swells and forms a typical colloidal solution.

The grade of cement depends upon: First, the quality of rubber used. The addition of Pontinac or other highly resinous rubbers gives a thick, viscous cement of little holding power. Second, the kind and amount of solvent used. And third, upon the amount of mineral filler present in the stock.

Vulcanization

Vulcanization is effected by two principal methods. The first, hot process, is by heating rubber with sulphur. And the second, cold process, consists of treating it with a dilute solution of sulphur chloride.

Hot Process

This is effected in three principal ways. The first, heater cure, subjects the article to the action of live steam under pressure. The second, press cure, subjects

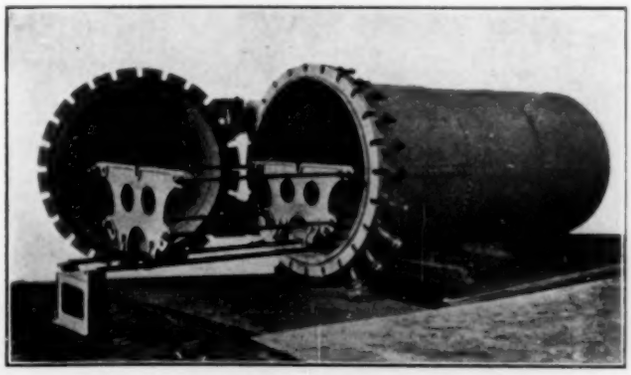


FIG. 6—DIRECT STEAM OR OPEN HEATER

it to hydraulic pressure and heats it indirectly by the steam-heated faces of the press. The third method, called the autoclave press, is a combination of the first two. The important factors in hot-process work are time and temperature. The latter is expressed in pounds per square inch steam pressure. Factory cures read so many minutes at so many pounds of steam, as 30 at 30 for example.

Live Steam Cure

Fig. 6 shows a direct steam or open heater. It consists of an autoclave equipped with a pressure gage, thermometer and self-regulating valve. An article to be cured by this method must first be wrapped tightly with a wet cloth. This is narrow and resembles both in appearance and application a bandage. Schidrowitz claims that where possible the live steam cure is best, since the steam seems to act as an accelerator. This method can not be applied to articles containing much oil substitute, owing to the saponifying action of steam at high temperature. Care must be taken not to release the pressure on the autoclave too rapidly lest the article become porous. The loss in time and heat occasioned by blowing off is quite considerable.

Press Curing

Fig. 7 shows a small multiple press. The heads A, B and C are heated by live steam under pressure. C is directly connected to the piston of the hydraulic press. In regard to this method, Schidrowitz makes the statement that in general, with given heat conditions, the better result is obtained by higher hydraulic pressure. The even distribution of pressure permits the production of relatively large articles where homogenity is desired. Another advantage of the press is that the steam and hydraulic pressure can be regulated separately. Its great advantage is the difficulty in controlling the temperature of the heads due to condensation. If one face is hotter than the other the surfaces will not receive the same degree of vulcanization.

Autoclave Press

As stated previously, this method is a combination of the two above described. Articles to be cured are

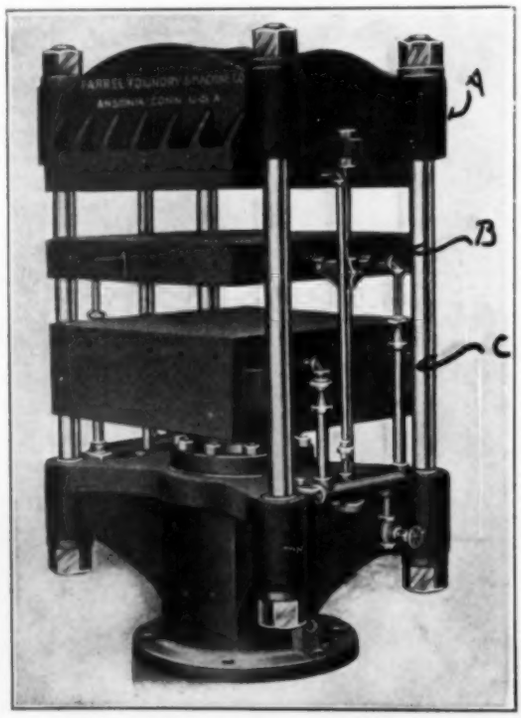


FIG. 7—SMALL MULTIPLE PRESS

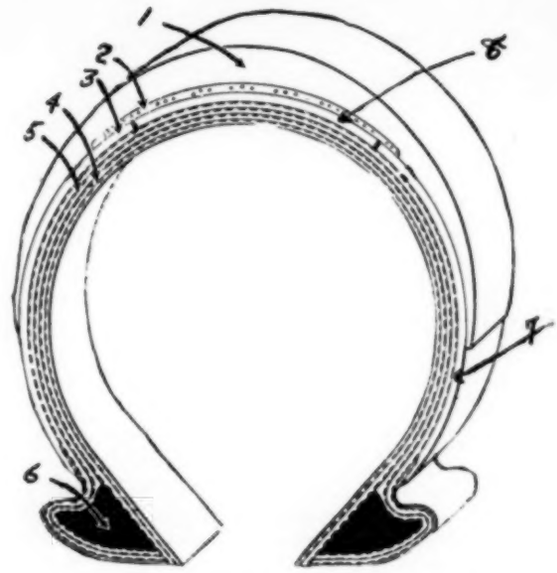


FIG. 8—SECTION OF AN AUTO TIRE

subjected to hydraulic pressure while contained in an autoclave. For example, auto tires which are cured in this manner, are built up on forms, clamped in molds and laid flat in the autoclave, the floor of which forms the head of the press. The molds are subjected to pressure between the top of the autoclave and this piston head. Steam is turned on just as in live-steam curing. For auto tires the hydraulic pressure amounts to around 1000 lb. per square inch.

Cold Vulcanization

In this process, rubber is vulcanized by the action of sulphur chloride, S_2Cl_2. A 2 to 3 per cent solution in carbon bisulphide, CS_2, or in carbon tetrachloride, CCl_4, is used. Articles over 4 mm. thick cannot be cured in this manner since by the time the interior was vulcanized the surface would be over-cured and brittle.

The Manufacture of Tires

This subject is so broad that a complete discussion is entirely beyond this article. Ten years ago, when the tire industry began, they were made complete, that is, without a separate tube and casing as is the practice at present. This method was very expensive and tires were hard to make and hard to repair.

If the reader will refer to Fig. 8 we will take up the construction of an auto-tire casing, and consider the various parts and the necessary properties of each.

The principal parts are: Fabric, cushion gum, side strip, breaker strip, bead and tread.

Fabric.—Duck is frictioned as previously described. It is commonly cut on the bias, and the tire roughed out on a form. This is made of heavy cast iron, since it is not removed until the tire is cured, and must therefore stand the high pressure of the press. Numbers 4

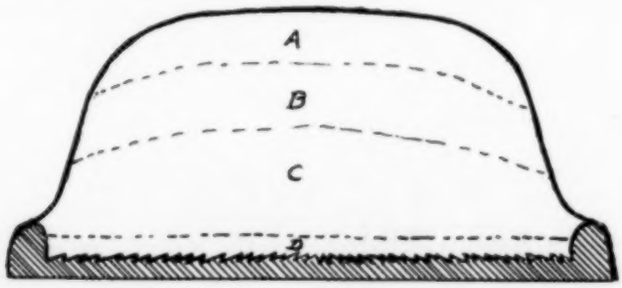


FIG. 9—SECTION OF TRUCK TIRE

and 5 show the layers of fabric. In good casings the fabric is made from long fibered or Sea Island cotton. The friction stock is very good, containing considerable rubber, no shoddy and as a rule no sticky materials. Much depends on the fabric, for it is the backbone of the tire.

Cushion Gum.—The gum cushion is indicated by 8. Its purpose is to add resiliency to the casing. It is a narrow strip of very good rubber, and as is shown, goes around directly beneath the point where the tread and the road surface make contact. It ordinarily contains around 80 per cent rubber.

Side Strip.—The side strip, 3 and 7, covers the sides and extends up under the tread to the gum cushion. It is not necessary to use such good material at this point. We usually find about 50 per cent rubber.

Breaker Strip.—This, 2, is a loosely woven piece of very strong cloth. It is placed over the gum cushion and covers the ends of the two pieces of side strip, thus tieing them together. This is its purpose.

Bead.—The bead, 6, consists of a ring of hard rubber either with or without reinforcement by steel cable. Its shape depends on whether straight side or clincher rims are to be used. It is made up separately and applied between the layers of fabric.

Tread.—The tread, 1, is the most important part of the casing. It must be tough and hard but not brittle. Being in contact with the road surface, its wearing power decides the life of the tire. Because of the high degree of toughness necessary, one will usually find in it considerable quantities of zinc oxide. Ordinarily around 50 per cent is used to about 40 per cent rubber. The remainder is sulphur and miscellaneous filler.

The procedure of building up a tire casing is then as follows:

The operator begins with the fabric. The bead is placed in position between the layers. Next the gum cushion is applied. The side strips cover the sides and are bound together by the breaker strip. The tread goes on last. It must not be taken that any large sections are put on at once. Each separate part, except, of course, the breaker strip, is made up of a number of thin layers.

A tire casing so prepared is taken to the curing room, clamped in a mold and placed in an autoclave press for vulcanization. The period ranges from one to two hours at 45 to 55 lb. of steam. Where non-skid tires are being made the mold has depressions corresponding to the studs desired. The hydraulic pressure forces the tread into these, so that when the mold is removed the studs stand in relief. After trimming and wrapping the tire is ready for shipment.

Inner Tubes

A casing so prepared requires a strong elastic and air-tight inner tube. For this purpose a stock containing around 80 per cent rubber is used. The filler may be antimony golden sulphide, if non-blooming tubes are desired, or it may be simply zinc and iron oxides. Gray tubes have varying composition, depending on the maker's experience. The stock is sheeted very thin and the tube built up lengthwise on a mandrel by rolling. It is wrapped with cloth and cured in live steam. After splicing the valve is set in place and it is ready for use.

Solid Tires

Fig. 9 illustrates a section of a truck tire. These are usually built up on a ridged steel rim. D indicates the hard base, which is very nearly ebonite. Its purpose is to bind the tire to the rim. C is the elastic part and serves the same purpose as the air of a pneumatic tire. B is the next layer and is slightly tougher than C. A is the tread and must be very strong and tough. It usually contains 40 to 50 per cent rubber, 2 to 4 per cent sulphur and the rest mineral filler.

Solid tires are also cured in an autoclave press.

Belting

Duck for belting is dried and frictioned as has been described. It is cut lengthwise into strips whose width depends, first on the size of the belt, and second upon the method of manufacture. One manner much used is to form the inner plies of strips having the same width as the belt. These are stacked and placed in the middle of a strip of double the width. They are next drawn through an opening having flared edges which fold the bottom strip over the top and form a butt joint. The belt is then passed between rolls which press the plies firmly together. At the same time the joint is covered by a narrow strip of rubber. While some of the most expensive belts are made without covers, it is usually the practice to have them. In fact, on some grades of conveyor belts even a gum filler is placed in the center of the belt. When the belt is to have a cover, this is commonly calendered on to the outside ply of duck before application to the belt.

Another method which is said to give a stronger belt is to cut each strip of duck twice as wide as the belt. The first strip is folded on itself, so as to form a butt joint. This strip is placed on the next with its joint down. The process is repeated until the belt has the desired thickness. The top joint is covered with a narrow strip of rubber or a cover placed on the belt.

The belt is cured in two steps. First it is tightly coiled and wrapped so that only the edges are exposed. It is then placed in a large heater where it is subjected to the action of live steam. When the edges are cured it is finally vulcanized in a long press. It is tightly stretched and cured in sections of from 10 to 30 ft. in length.

With conveyor belts the cover is always made of good material, but for transmission it is customary to use cheap covers and put the most expense into the friction, so that the plies of duck will be firmly held together.

Balata Belts

A discussion of rubber belting would not be complete without mention of balata. This substance, while having the same chemical formula $(C_{10}H_{16})_n$ as rubber, has almost no elasticity. Its behavior with heat is also quite different. At slightly over 70 deg. C. it softens, and by heating it a little higher duck may be impregnated with it. A balata belt is built up just as previously described under rubber belting, using, however, sheets of this treated duck. Successful operation depends considerably on keeping the balata at the proper temperature for working. When the desired thickness of belt is reached it is subjected to hydraulic pressure in a moderately heated press, thus forcing the balata substance well into the pores of the fabric. When it cools the balata sets and the plies are firmly bound together.

Balata belts are, as a rule, very good. The use for which they are best fitted is that of running under damp conditions.

Hose

This forms one of the most important branches of the rubber industry. Like the manufacture of tires, this subject is also so broad that we are unable to go deeply into it. The subject may be sub-divided as follows: Cotton jacketed, braided, and wrapped.

Cotton Jacketed.—This includes the various grades of fire hose, and is made up of a rubber tube with either a single or double cotton jacket. The tube is made from a calendered sheet, cut wide enough to give the proper

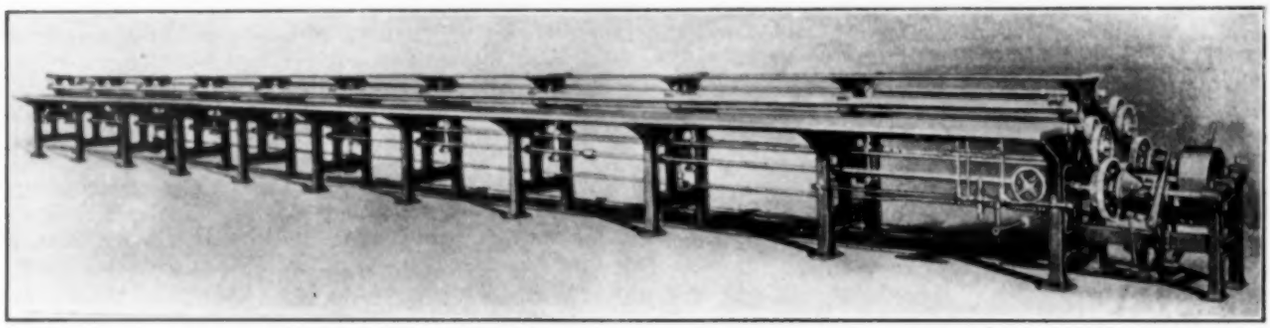


FIG. 10—52-FT. COMBINATION HOSE-MAKING AND WRAPPING MACHINE

circumference and a small lap. This lap is cemented and the tube given a semi-cure. This fixes the cement and also gives the tube enough strength for subsequent operations. The cover is woven separately. It is placed on a long table and a rod passed through it. This carries a cord, to which is attached the tube. The workman pulls the tube first through cement and then through the cover. The coat of cement is called the backing. Then he fills the hose with steam under pressure, which expands it, thus forcing the cement well into the cover and at the same time vulcanizing the rubber.

Braided Hose.—This variety is of practically recent introduction, but is growing in popularity and seems to be very good. Garden hose is one example of this class. The tube is run on a tube machine. For this purpose a soft stock is necessary. It is warmed to a sufficiently high temperature on the rolls to make it plastic, and in this condition it is forced through a die which may be adjusted to give any desired thickness of wall. A worm similar to that used on a sausage machine carries the stock forward and forces it through the die. In this manner hose of any length can be made. For this reason it is sometimes called continuous hose. Cheap gas tubing, and, in fact, most all small size single wall hose, is made in this manner.

Having formed the tube on the tube machine, it is then led through a braiding machine, where fabric is braided around it. The tube may or may not have been coated with cement, depending upon the kind of stock used and also on the purpose of the hose. The operation may be repeated as often as desired. When the required number of plies is produced the hose is sent through another tube machine, where the cover is placed on it in much the same manner as the tube was formed.

Vulcanization is effected in a press. During the operation air pressure is maintained inside the hose, which forces the rubber well into the meshes of the loosely woven braided fabric.

Wrapped Hose.—In this class I will include all those varieties of hose made up of a tube, cover, and friction. The friction is simply duck, coated as previously described under frictioning. Under this head come many varieties of hand-made, machine-made, and semi-machine-made hose.

All varieties are, however, built up on a mandrel. The tubes used may be made from sheets as described under cotton hose, or may be run on a tube machine. In this case they are placed on the mandrel by the aid of compressed air.

Short length varieties, such as air-brake and tank hose, are mostly machine made. This machine is not very complicated and consists principally of three rollers, two on the same plane and the other immediately above and half-way between the other two. The mandrel with the tube is placed on the rolls, the correctly cut strip of friction applied, the top roll let down and the machine started. The tube is quickly wrapped. The cover is put on in the same manner. Armored hose is made by placing a spiral of wire between the plies as desired.

Long length hose is made in just the same way, except that here the machine is much longer. The length is usually 52 ft. and the hose is made in 50-ft. lengths. Fig. 10 is a photograph of such a machine. Hose made in this manner is wrapped with cloth and cured in live steam.

Molded Goods

This group includes valves, gaskets, and thousands of cheap articles. These are built up on a mold and cured in a press. Because of the low price at which they are sold, much attention is given to efficiency and speed of operation.

Dipped Goods

Under this head come rubber gloves, some surgical goods, and other thin rubber articles. They are built up on a form. A single carrier holds often as high as 100 of these. After dusting them with soapstone they are dipped in rubber cement. After drying the process is repeated until the desired thickness is produced.

Such articles are cured while on the forms by dipping in a solution of sulphur chloride; that is, by cold vulcanization. After curing, they are well washed, first with water, then with sodium carbonate solution, and finally with water. After drying they are peeled off the form, dusted with soapstone, and are then ready for shipment.

Spreading

Under this head comes the manufacture of proofed textiles. The process consists of spreading a very thin layer of rubber evenly over the fabric.

The spreading machine is a long, steam-heated iron table, provided with rollers at either end. The cloth as it is unwound from one roll passes under an iron "doctor," where it receives a certain quantity of cement. It then travels over the surface of the table, where the solvent is evaporated. The process is repeated until the desired thickness of coat is obtained.

Since considerable solvent is used in spreading, the tables are covered by hoods which lead to a refrigerating system, where most of it is recovered.

Such material is cold cured by passing it through sulphur chloride solution. The product is well washed and dried.

Shoddy

At various places in this article mention has been made of shoddy or reclaimed rubber. This branch of the industry is very large and the material finds application to a more or less extent in all branches of rubber practice except tire making. It has been said that two-thirds as much rubber scrap comes back to the factories as the crude rubber which they receive. How many times rubber is used over and over again is not known.

but it is undoubtedly a large number, and forms a good illustration of the reincarnation theory. However, as it is successively used it descends in the scale of value. Tire scrap furnishes the best grade, since it is made from the best of rubber and seldom contains any shoddy. This goes into other materials, such as steam hose, which in time wears out and comes back to be made into still a lower grade.

A true reclaiming process would give back the rubber in its original condition, minus the sulphur which was chemically added on during vulcanization. So far no such process has been brought forth. What is done is merely the freeing of the rubber from the fabric and depolymerizing it so that additional sulphur may be added and the material revulcanized. The alkali and acid processes are the most important.

Alkali Process.—The rubber scrap is finely ground between rapidly rotating knives. This material is placed in long cylindrical drums fitted with paddles. Here it is heated for around twelve hours with a 10 to 20 per cent solution of caustic soda. This treatment removes all saponifiable organic fillers, such as vegetable oils and substitute, and also the free sulphur. The fabric is destroyed and rendered soluble. The particles of rubber are secured by screening the tank liquor. They are well washed on a washing mill. After working a little they stick together and may be sheeted. The sheet is dried either by vacuum or by working on a hot mill. If the scrap used was rather low grade, it may be necessary to add tar, heavy oil, or other material to give it cohesiveness.

Acid Process.—This process is the same as the alkali, except that a dilute solution of sulphuric acid is employed instead of caustic soda. The product is not considered equal to that of the alkali process, and oil must be added to give it the desired degree of cohesiveness.

CONCLUSION

In this and the previous article I have endeavored to outline briefly the most salient points in respect to this industry. Rubber is a close competitor with steel in the number of things which may be made from it. It surpasses steel in the range of properties obtainable. The industry is of great importance, and the future will doubtless call upon it more and more.

The Mechanical Principles of the Blast Furnace—II

BY J. E. JOHNSON, JR.

The Support of the Charge Column

The support of the charge column is made up of at least four elements. First, the upward pressure of the gas. Second, the friction of the charge on the sides of the shaft. Third, the vertical upward thrust against the charge from the downwardly converging slope of the bosh walls. Fourth, flotation in the molten mass of iron and cinder in the hearth. To these we might almost add a fifth, the dragging of the pasty zone against the walls at the top of the bosh, but this may be counted as a part of the friction, especially as we have no means of measuring either.

The weight of the charge column is very generally over-estimated by those who have not made calculations upon it. It is ordinarily assumed that this weight is 50 or 100 lb. per square inch, but obviously this is not true. If we estimate that three-fifths of the charge by volume is coke with a specific gravity of 0.45, and two-fifths ore and stone with a specific gravity of 2.5, we shall have a column 1.18 times the specific gravity of water. Taking the height from the tuyeres to the stock line of a modern furnace as 70 ft., the water pressure corresponding to this height is 30 lb., which would correspond to a weight of charge column of 35 lb., if the materials descended to the hearth in the condition in which they are charged. But as a matter of fact the ore loses about 25 per cent of its weight in the form of oxygen carried off by the ascending gases, while the limestone loses 40 to 45 per cent of its weight through decarbonization. Moreover, in many cases the bulk of the ore is vastly increased by the great volume of extremely light, flocculent carbon deposited upon it by the action of the gas. As a net result the weight of the charge column is greatly diminished, while considering only that part of it down to the base of the shaft, its diameter and area are greatly increased by the outward batter of the furnace still further reducing its weight per square inch.

In my paper "Notes on the Physical Action of the Blast Furnace" before referred to in this serial, I have embodied some calculations on this subject which are probably just as applicable to present conditions as they were to the conditions on which they are based, and are therefore quoted.

In order to have a concrete example on which to base calculations, let us take, as representative of present conditions, the Isabella furnace, of which the more important data are given in Mr. Gayley's paper on the dry blast. The lines of this furnace are shown in that paper.

Let us assume, for an average of summer and winter conditions, that the output is 400 tons per day and the burden per 10,000 lb. of coke is 22,000 lb. of ore and 5500 lb. of limestone; the coke per ton of iron is 1900 lb. and the ore per cent through the furnace, to agree with the above assumption, 53.6 per cent.

The total content of 18,090 cu. ft. are divided as follows: 1193 cu. ft. in the hearth, 3087 in the bosh, and 13,810 in the shaft above the bosh.

Assume that coke weighs 28 lb., ore 135 lb., and limestone 90 lb. per cubic foot—figures sufficiently exact for our purpose, then the volume of a charge will be 357 cu. ft. of coke, 163 of ore, and 61 of stone, or 581 cu. ft. in all. Each charge weighs (as charged) 37,500 lb.; hence the initial average weight per cubic foot is 64.5 lb.

The weight of stock in the shaft of the furnace can easily be calculated from the weight and volume of the charge given above, but the result so obtained is entirely too high for several reasons. In the first place, the ore swells enormously in volume under the action of the gas and the deposition of carbon. Secondly, the oxygen of the ore is nearly all removed, lightening it about 30 per cent. Thirdly, all the CO_2 of the limestone is driven off, lightening it 44 per cent.

It is impossible to express the sum of all these effects with quantitative accuracy, but if we assume that the ore doubles in volume, and that the limestone decreases 44 per cent in weight by the time the charge has reached the top of the bosh, and neglect all the other conditions, we shall certainly be on the safe side in estimating the total lightening effect.

This gives a final reduced weight of 47.2 lb. per cubic foot, and if we assume the change to have occurred uniformly as the charge descended, we can calculate the weight of stock in the shaft, which will be, on this basis, 755,000 lb.

The difference of pressure between the tuyere-zone and the stock-line is 14 lb., and this is evidently all used up in forcing the gas formed at the tuyeres through the column of stock.

In the absence of knowledge as to the rate at which the pressure falls, we may reasonably assume that it is proportional to the distance traversed. This gives a

loss of 2.6 lb. to the top of the bosh, leaving a pressure at that level of 11.4 lb. more than at the stock-line. Leaving out of account what goes on below that level, it may be observed that, since the stock exerts a resistance of this amount to the passage of the gas, the gas must also exert a resistance of an equal amount to the passage (descent) of the stock, since action and reaction are always equal and in opposite directions. In this resistance to the descent of the stock will be found the cause of slips.

The pressure of 11.4 lb. on an area of 21 ft. diameter gives a total pressure of 568,000 lb.; but the difference of pressure is all that counts, and each zone is a little larger than the one above, so that the whole difference of pressure only acts on a central area equal to that of the stock-line. A deduction of 184,000 lb. must therefore be made from this 568,000 lb., and the net resistance offered to the descent of the stock by the blast is thus 384,000 lb., which is more than half of the entire weight of the column of stock. From the unbalanced remainder must be deducted the weight necessary to overcome the friction of the stock on the walls, which it is not practicable to estimate in figures. Probably it is not less than from 10 to 20 per cent of the weight of the column, and may easily be more. Assuming it to be 15 per cent, it amounts to 113,000 lb., which added to 384,000 gives 497,000, or about two-thirds of the total weight of the stock-column.

Under normal circumstances the remaining third of that weight is enough to bring the column of stock down; but if any local derangement takes place, and the pressure ceases to fall at a regular rate, we have a condition the trouble-producing power of which is cumulative, for owing to the increased resistance, the flow past the obstructed point is reduced, and with it the friction and counter-pressure below, while owing to the damming action of the obstruction, as the engine continues to blow the same quantity of blast, the pressure soon runs up, and as the velocity is reduced the high pressure that normally exists only in the lower part of the furnace extends up under the obstruction. This compresses the obstruction more, and forces it more tightly against the furnace walls, while at the same time, by reason of the greater pressure, it becomes denser, and offers still greater resistance to the passage of the gas, which in turn augments all the other effects, until the furnace is "stuck" tight. The "plug" is in a conical passage and cannot yield backwards, and things remain in this condition while the stock below continues to settle until a cavity is formed underneath the "plug." Finally, through some accidental weakness in the obstruction, or through the slacking of the blast and reduction of the pressure under it, which allows the plug to come loose, the condition is broken, and the suspended mass falls.

As to the cause of the violent ejections of stock, some of which take the bell along, there has been much speculation, and various explanations have been made, none of which have seemed adequate. The true explanation seems to be that the whole furnace below the plug is a reservoir of compressed gas (this being especially true of the cavity formed under the obstruction), and when this latter gives way it is like knocking out the keystone of an inverted arch under pressure—the instant the arch is broken the compressed gas has ample energy to carry away, in its sudden escape, part of the overlying stock.

The greater the cavity the longer the "blow"; while the further down in the furnace the obstruction lies the higher the pressure under it is likely to be, and the greater is likely to be the mass of material above it through which the gas must make its exit and portions of which it will carry along.

To the initial increase in resistance to the passage of the gas several causes may contribute; but, if the furnace is not scaffolded, the most important one is the deposition of carbon-dust through the splitting up of the CO into CO_2 and C. Both the extent of this action and the time of its beginning vary greatly with the character of the ore through which the gas passes, as has been shown in various papers read before the Institute and elsewhere. It has also been shown that the action proceeds with great rapidity when it has once begun, thus localizing it in some cases to a certain restricted zone in the furnace, both below and above which the charge is more open—below, by reason of its downward movement and the increased shaft-diameter reached thereby; above, because no carbon has yet been deposited in it. The slips thus tend to be localized in this zone; and hence most of the slips from a given furnace, which slips habitually, would have about the same degree of violence. Practice shows this to be the case.

The resistance of the gas column to the descent of the charge has been treated above as if it existed only above the top of the bosh, though as a matter of fact it exists all the way down to the tuyeres, but has not as great an effect in the bosh as it has above that region for the reason that in the latter region the area on which the smaller blast pressure acts is greater than that on which the larger pressure acts, that is to say, the pressure at the top of the bosh is smaller but the area of this zone is larger, while the hearth pressure is larger but its area is smaller. Therefore the difference in the products of these two is much less important than it is in the case of the bosh zone and the stock line where the greater pressure exists over the greater area and the smaller over the less.

In further explanation of the lifting action of the gas current on the charge column it may be remembered that one of the approved methods of lifting grain consists in delivering it into a vertical pipe up which a current of air is traveling at a high velocity. This is not in any way connected with lifting water by suction, through the removal of air, which is limited to 34 ft., but may be carried on practically without reference to the height. But when we find even approximately what the actual velocity of the gas current is, we realize that the present action is not altogether similar to this.

We have already seen that the velocity through the shaft is approximately constant so we can determine it roughly by reference to the hearth conditions only.

Assume a furnace of ordinary dimensions with a 16-ft. hearth blown with 45,000 cu. ft. of blast as measured by piston displacement or, say, 40,000 cu. ft. actual at atmospheric temperature and pressure compressed to 15 lb. pressure, and heated to 1200 deg. The absolute volume becomes $40{,}000 \times \frac{1660}{530} \times \frac{15}{30} = 62{,}600$ cu. ft. The area of the hearth empty is 200 sq. ft. but this is filled with coke, through whose voids only, the blast must pass. Assuming these conservatively as one-fourth of the total (see below) we have a net area certainly not to exceed 50 ft., through which all the blast must pass. This would give a velocity of $\frac{62{,}600}{50} = 1250$ ft. per minute, but it must be remembered that this refers to the voids in the coke by itself and takes no account of their obstruction by molten iron and slag which as we shall later see is very great. If we assume that they amount to 50 per cent of the original area we shall probably be safe and this would double the velocity, making it 2500 ft. per minute or approximately 30 miles per hour and it may well be that this figure is too low rather than too high.

This velocity alone, however, is not sufficient to ac-

count for the drop in pressure in so short a distance but there is another factor of great importance; the roughness of the passage through which the gas column must pass, the "wetted surface" of the conduit (the stock column) is almost infinite and when we remember the vast effect of a slight increase in the roughness of any conduit on the friction of the fluid passing through it we have no difficulty in understanding the pressure drop even though the velocity be no more than 30 miles per hour, and, of course, the pressure drop is the direct measure of the lifting power of the charge rather than the velocity. In other words the action in this case is rather that of a leaky piston than the transportation of loose material by a rapid air current.

The Friction on the Walls

The effect of the friction on the walls is very great and must not be ignored though we have no means of estimating it accurately. It has been found in cylindrical grain bins that something like two-thirds of all the weight of the grain is taken on the side walls, but we cannot expect so large a percentage to be carried this way in the case of the blast furnace because the stock is kept in a more or less violent state of agitation by the current of gas rising through it. A strong upward current of gas produces a tremendous effect in the internal friction of a loose mass of solid matter particularly one containing much fine material, the agitation of the smaller particles makes them act almost like a liquid and exercise a corresponding influence on the larger particles. A mass of dry sand which might stand at a slope of 20 deg. when quiescent would not stand on one of 5 deg. if agitated by a current of air from below. On the other hand, the pressure of the charge column against the sides may be very much greater than what we should expect from its weight alone, that is to say, the pressure which the walls would receive if considered as a vertical retaining wall for an embankment. This is because of the tremendous swelling which frequently takes place in the ore due to carbon deposition.

These conditions make it exceedingly difficult to apply even our slight knowledge of the internal friction of such materials as compose the furnace charge to determining the effect of wall friction quantitatively, but we do know that the charge sometimes hangs in the furnace at a height far above the beginning of the pasty zone and sometimes remains hanging even when the blast is taken entirely off. This can only be due to wall friction and indicates that this may sometimes exceed 100 per cent though undoubtedly its normal amount is very much smaller.

THE SUPPORT DUE TO THE UPWARD COMPONENT OF THE REACTION OF THE BOSH WALLS

Obviously if the bosh walls were continued down until they met in a point the inverted cone so formed would support the stock column completely, and the portion of this cone which actually exists furnishes its portion of support, this, of course, ignores all questions of flotation from the liquid in the hearth which we may exclude for the present. Thinking only of the steep slope of the bosh and of what a small frustum of a complete cone it is, we might be inclined to dismiss as insignificant the amount of this support especially in view of the modern tendency to build furnaces with large hearths and extremely steep, short, bosh slopes. But even in the most extreme of these furnaces this would not be correct, for the amount of this support is obviously proportional, other things being equal, to the difference in the area of the zones projected into a horizontal plane. Even with a 22-ft. bosh and 17-ft. hearth this difference is 40 per cent of the bosh area and it seems reasonable to assume that 40 per cent of whatever unbalanced pressure may exist down to the tuyere zone is taken by the bosh slope even in this case. Incidentally this indicates that a change in hearth diameter of 1 or 2 ft. may have a considerably greater effect in the mechanical operation of the furnace than we might at first glance suspect. That this is true we have an abundance of experimental evidence.

In considering the shape of the furnace we shall presently note that as blast pressures have risen supplying more support for the charge column, hearth diameters have increased leaving the bosh area smaller and so supplying less support. This at least suggests that the proper descent of the charge column only takes place when the sum of the resistances thereto does not exceed a certain total.

The Flotation of the Charge Column in the Liquid

This is an exceedingly complicated question. It is rather illuminating to consider the volume of molten material in the hearth at its maximum. Let us assume that a 500-ton furnace casts four times per day and that one-fourth of the total cinder, or 300 lb. per ton, is in the furnace before cast, and that the hearth is 16 ft. in diameter which gives an area of 200 sq. ft., all about in accordance with modern practice.

We may assume that the volume of iron at the high temperature at which it exists in the furnace is 5 cu. ft. to the gross ton, and that molten slag weighs 150 lb. to the cubic foot, so that 300 lb. of slag have a volume of 2 cu. ft., which added to the 5 cu. ft. of molten iron makes a volume of 7 cu. ft. per ton. One hundred and twenty-five tons of iron would therefore correspond to a volume of liquid of 875 cu. ft., or sufficient to fill the hearth to the depth of a little less than 4½ ft., in other words not very much over half way up to the tuyeres.

On this basis we could dismiss the idea of flotation altogether if we considered the charge column to end at the tuyeres, but as a matter of fact we know that it does nothing of the kind, and that it must settle until it rests upon the hearth bottom, or until it is floated by the liquid in the hearth. Of course, if the stock column were only 8 or 10 ft. high it would readily be floated by the liquid, but when we consider the great height of superincumbent stock resting upon it, and forcing it down, we realize that it may be forced to the bottom of the bath at least in furnaces with a small blast pressure and shallow bath.

The result of forcing the stock column down into the bath is to raise the level of the liquid very greatly since the latter can occupy only the interstices in the coke. We do not know what these amount to exactly, but some careful experiments I made several years ago showed that the voids in thoroughly mixed crushed ore were about 33 per cent, while the percentage of voids existing between spheres closely packed is about 35 per cent of the volume of the spheres or about one-quarter of the volume of the space occupied. We may therefore assume without chance of great error that the percentage of voids in the coke as it exists in the hearth and bosh do not exceed 33 per cent of its net volume, or one-quarter of the total, which means that the height of the liquid must be four times as great as that estimated above or nearly 18 ft., which would bring the liquid well above the tuyeres if the coke column extended down to the bottom of the hearth. This is at least partly in accordance with the facts, since, of course, we know that the cinder will flow back into the tuyeres and rise in the penstocks to a considerable height if the blast be taken off before first "flushing" the cinder out of the furnace.

It is instructive to make an estimate of the floating

effect of the liquid bath even though we must use approximate figures.

Assume coke to weigh 28 lb. per cubic foot loose and to contain 25 per cent of voids, then its weight "solid" is 37 lb. per cubic foot. The weight of slag per cubic foot is as above given about 150 lb. and of iron 450 lb.; on the basis of the weights of these in the hearth and their combined depth of 17½ ft. in the interstices of the coke, the depth of slag alone would be 5 ft. and that of the iron 12½ ft. The buoyancy of the coke in slag per cubic foot of space is three-quarters of (150 — 37) or about 85 lb. and for the whole depth of the slag it is 425 lb. per square foot upward thrust, for the iron it is three-quarters of (450 — 40) or about 300 lb. per cubic foot and would be twelve and one-half times as much if the coke were submerged in the iron to the bottom of the hearth or 3750 lb. per square foot, this added to the 425 lb. per square foot due the submersion in the slag makes 4175 lb. per square foot or 29 lb. per square inch, which added to the 12 lb. due the blast pressure above the top of the bosh would make 41 lb. per square inch of total upward pressure on the base of the stock column or *considerably more than its total weight* without any allowance whatever for friction on the walls or support on the slope of the bosh. It is perfectly clear therefore that the weight of the stock column is not sufficient to force it to the bottom of the hearth when the latter contains much molten material but that it is submerged only to such a depth as supplies the upthrust not furnished by the other three forces. That the buoyancy of the base of the charge in the liquid in the hearth is a decided factor is proved by the fact that furnaces always settle very much more, immediately after cast than they do at any other time. Very frequently a furnace will settle perceptibly even as a result of flushing, and there is no reason to doubt that this is due to the removal of a portion of the buoying action of the liquid.

That the charge column does not rest on the bottom at least before cast time a very interesting proof has recently been given by Mr. F. L. Grammar.* If gaging prove that a furnace is settling regularly at the rate of 30 in. per half hour previous to cast and if during the half hour occupied by cast it settles 60 in., then obviously it could not have been resting on the bottom at the beginning of cast.

There is much reason to believe that the liquid slag not only stands in the furnace above the level of the tuyeres but that it is blown up through the interstices in the coke to a level many feet higher. The viscosity of the slag is considerable, and the blast has difficulty in making its way through it, as anyone will realize who has seen or even heard the slapping and blubbering which accompanies this action when it takes place under abnormal conditions when the slag is standing at a high level in the bosh and only a little blast passing through it (conditions which only exist with a badly deranged furnace) and we know that if the blast be taken off the furnace too quickly, even though the slag be below the level of the cinder notch when it comes to rest, we are more than likely to have the cinder come back in the tuyeres, which, of course, can only happen if at least a part of the slag has been well above their level.

In order to form a picture in more easily comprehensible terms I have sometimes thought that we might take a glass tube some 2 in. in diameter, and insert into it, 1 in. from the bottom, some ⅛-in. nozzles piped to a supply of air under slight pressure, fill the tube with water to a level half way up to the air nozzles, pour in sufficient granulated cork or other light substance to fill the tube for a height of 10 or 12 in., and then blow air through the air nozzles in sufficient quantity to keep the water which is raised up around them by the descent of the cork, in a lively state of agitation. It is obvious that the cork would be supported partly by this flotation in the mass of bubbles into which the water would be converted, and partly by the ascent of the air through its interstices, and perhaps some of its weight would rest on the bottom of the tube.

Such a mental picture shows us how impossible it is to estimate exactly the value of each component in supporting the column of cork.

Limitations to the Size of the Furnace

The use of the formula for blast pressure as a tool of investigation enables us to discover the reason for certain facts of practice not otherwise easily understood. If furnaces be built larger they must obviously be blown with a proportionately increased quantity of wind if they are to yield results commensurate with their size, and in fact this is always expected of them. There are a few furnacemen who have built furnaces much larger than is customary for the tonnage which they desired to produce, but this practice is very rare though extremely sensible and advantageous. Generally considerations of corporation policy force the manager to produce an amount of iron approximately proportional to the volumetric contents of his furnace. Proceeding on the assumption that this condition must be met, we obtain the following results: W, the quantity of blast per minute, to be proportional to the capacity of the furnace, must vary as D^2H with the 22-ft. x 90-ft. furnace and 45,000 cu. ft. of wind $\frac{W}{D^2H} = 1.03$, and any other furnace with dimensions D_1 and H_1 must be blown with $1.03\ D_1^2H_1$ cu. ft. of wind to maintain this proportion. Then from the general formula we have

$$P_1^2 - P_2^2 = 0.0080\ \frac{(1.03)^2(D^2H)^2H}{D^4} = 0.00085H^3.$$

For the 22-ft. x 90-ft. furnace the pressure figures out as follows:

$$P_1^2 = 216 + 0.0008 \times \frac{(45{,}000)^2 \times 90}{22^4} = 216 + 0.0008 \times \frac{2{,}025{,}000{,}000 \times 90}{234{,}000} = \frac{80 \times 202.5}{26} + 216 = 624 + 216 = 840 \therefore P_1 = 29 \text{ abs.} - 14.7 = 14.3 \text{ lb.},$$

which is just about the actual pressure for these conditions.

For a furnace one-half larger and blown with proportionately more wind we should have then $P_1^2 = 216 + 624 \times (1.5)^3 = 216 + 2100 = 2316$ or P_1 abs. $= 48.1$ or a gage pressure of 33.4 lb. That is to say, if the shape and relative dimensions remain the same, the difference of the squares of the absolute top and bottom pressures increases as the cube of the height. Therefore, if we build a furnace 50 per cent larger in all its dimensions than the present 90-ft. x 22-ft. furnace, and blow it with a proportionately increased volume of wind, we shall have a blast pressure of 33.4 lb. as against the normal pressure of the present size furnace of 14.3 lb., or nearly two and one-half times as much for an increase of 50 per cent in height.

The result of this is two-fold. First, we receive no return whatever for the power expended in compressing the blast. It is a necessary evil and nothing else. Therefore the power expended for this purpose is wasted from more useful purposes. Moreover the investment required to blow higher pressures increases all along the line, not quite in the same proportion, but still at a very rapid rate, and the interest and depreciation on this surplus investment is therefore an absolute loss. Second, the regular descent of the stock is made increasingly difficult and a point would soon be reached where it would become impossible.

*Private communication.

Referring to the detailed calculation of the Isabella furnace given above it will be seen that the pressure per square inch of the stock column, referred to the area of the top of the bosh, figures out to about 15 lb., or to put it a little more accurately that the blast pressure in this case is just about half of the total stock column pressure without undue allowance for expansion of the ore. A greater height from the top of the bosh to the stock line may reasonably be assumed to yield a proportionately increased pressure of the charge column. This in our assumed furnace 50 per cent larger in all dimensions than the modern 90-ft. x 22-ft. furnace would give a stock column pressure at the top of the bosh of about 22.5 lb., while the blast pressure at that point, on the basis of a uniform drop in pressure from top to bottom, would be one-fifth less than the tuyere pressure of 33.4 lb. or about 27 lb. In other words the gas pressure alone at this point would be materially more than the weight of the charge column, and the latter would therefore be unable by any possibility to descend regularly, since we have seen that there are three other important factors resisting it.

It is easy to see then that there are natural laws which prevent building furnaces of more than a certain height and corresponding diameter, and it is a matter of record that furnaces over 100 ft. high have been less successful than furnaces of about 90 ft. high, so that in one case furnaces 106 ft. high were cut down to 90 ft., and at another plant which started with furnaces 100 ft. high, the next ones, built after several years' experience were made 90 ft.

These facts taken in conjunction with the blast pressure and stock column figures given indicate that 90 ft. is about the limit of the size of furnaces which may be blown to full capacity. If larger furnaces were built it would be necessary to blow them with less than the proportionate amount of wind. This would probably be a wise move within moderate limits since the larger furnace blown with the same quantity of wind, of course, requires a smaller pressure and allows a longer time in preparation for the stock, while the initial cost is nothing like proportional to the increase in capacity, and the smaller pressure required means a smaller investment in power plant.

Against this on the other hand is the fact that the radiation from a given furnace is practically constant, and therefore the faster the furnace is driven the less the radiation loss per pound of iron. From the data given in the article on thermal principles we know that the radiation and cooling water losses are 10 or 12 per cent. This means that if we made only half as much iron in the same size furnace these losses would run up to about 20 or 25 per cent.

Looking again at the other side we have reason to believe that in present practice furnaces are often probably blown a little harder than the rate at which the coke consumption is a minimum. A little fuel is sacrificed for the sake of increasing the output since this keeps down capital and labor costs to some extent.

The Shape of the Furnace

This is a subject which should properly be treated under operation, but the considerations we have discussed may be expected to exert certain influences upon the shape of the furnace, and some of these we may now consider.

We may well ask ourselves why has the furnace the shape which a slow and painful evolution has given it in all parts of the world: a cylinder at the top and bottom, the latter surmounted by an inverted cone of quite rapid outward batter, and this in turn by a frustrum of an upright cone of a much slower inward or convergent batter?

We have already seen that the shape of the furnace is approximately that which gives a uniform velocity of ascent to the gas column, its shape has been worked out upon purely empirical grounds, so that while this condition may be due to a coincidence it is more probably due to a relation of cause and effect entirely unknown during the development. There are certain other considerations of great importance and while we cannot attach quantitative values to them, and do not know all of their effects, we can point out some of their influences at least in a qualitative way.

The common base of the two conical portions of the furnace or the base of the short cylinder which connects them is universally known as the top of the bosh. What is this point?

It is in my judgment the zone in which the combustion of the oxygen of the blast to CO is complete, or viewing it from the opposite direction, it is the point at which the coke in its descent begins to be burnt by the blast. I have already discussed to some extent the fact that the lower part of this region is hotter than the upper, which at first sight it should not be if the combustion of the carbon to CO were going on uniformly throughout the zone, and I have given Professor Howe's explanation to me of this fact, that in the lower part of this region the coke was burned in the local and temporary excess of air partly to CO_2 with resulting high temperature, but that as this CO_2 rose through the excess of fuel in the bosh it was deprived of one atom of its oxygen by another atom of carbon, the whole forming CO instead of CO_2, and this reduction of CO_2 to CO is a distinctly cooling reaction. It is, therefore, to be expected that the upper portion of the bosh should be cooler than the lower portion, and this idea is not only not in conflict with, but is a confirmation of the conception that combustion of coke to CO is going on throughout the bosh, that being in fact the region of the furnace devoted to that purpose, in other words the combustion chamber. [Since the above was written I have been informed by John N. Reese of Youngstown of the results of some extensive investigations carried on by him, in which analyses of gas taken from the bosh at increasing heights showed contents of oxygen gradually diminishing and finally disappearing just about the top of the bosh. This is an independent experimental confirmation of the view here given far stronger than I had dared to hope for, and in my judgment forms convincing proof of its correctness.]

Above the top of the bosh we may assume that the material is in a "dry" condition. That is to say, neither the slag-forming materials nor the iron have begun to soften and become sticky. They then pass through a zone in which the sticky condition prevails, and finally as they become hotter and as the different slag-forming materials become more intimately mixed and therefore more fusible, both they and the iron pass out of the sticky condition into that of complete fusion with consequent liquidity and freedom of movement. It is obvious on a little consideration that this sticky zone is likely to obstruct both the passage of the gas upward and that of the stock downward, and in order that these shall not be prevented from moving in their appropriate directions it is obviously desirable that more room and slower velocity of travel should be provided at this point than at any other. This then should be the top of the bosh.

Granting that the top of the bosh is the point where the combustion of the blast to CO is complete and is also the point at which the solid materials enter the pasty state, this is obviously also the point where the gas generated in the hearth ceases to expand by combustion and drops below the critical temperature [since that is

by definition the free-running temperature of the slag]. From this zone upward it must contract by cooling through contact with the stock, and while, of course, it receives some increase in volume from the CO_2 of the limestone, this is much less than the contraction due to cooling.

From the top of the bosh downward the considerations which effect the shape are the decrease in the volume of the gas current as we approach the tuyeres (that is to say, its increase in volume as it rises from them), and the shrinkage, and eventual disappearance, of the coke.

We have then at the top of the bosh conditions which reverse within a short distance, first we have an increase in diameter necessitated both by the volume of the gas and the conditions of the stock column and then a decrease in diameter necessitated by opposite conditions, but it is evident that this reversal can not occur instantly and that instead of the two cones meeting at a fairly sharp angle, as it was once customary to have them do, there should be a transition zone either barrel-shaped as was once the custom, or a cylindrical section as is now the general practice.

Mr. Reese has recently pointed out to me that there is another reason for a cylindrical zone in this region which is that on some irons and some ores the furnace works on a very much more refractory slag than on others, and in consequence the pasty zone will be reached at a much higher level in one case than in the other and the maximum diameter at both heights can only be obtained by a cylindrical section.

To this Mr. Reese adds the valuable general law that the more infusible the slag the lower the bosh must be, which is borne out in a very broad way by all practice, both coke and charcoal.

Charcoal furnaces are ordinarily run with a very acid and fusible slag as compared with normal coke furnaces. Owing to its fusibility this slag melts at a higher relative elevation in the furnace than do ordinary coke slags. For this reason the top of the bosh of these furnaces should be higher relative to their height than that of coke furnaces. It has been found by experience that the height of the bosh of a charcoal furnace above the hearth level should probably never be less than 25 per cent of its total height and may be 28 or 30 per cent, whereas that of modern coke furnaces is considerably less than 25 per cent.

It is probable also that the cylindrical section in the pasty region has an advantage for another reason. The pasty zone must be penetrated by the charge column from above and by the gas from below, as long as this zone remains flat and horizontal, these actions can go forward without difficulty, but if the zone becomes arched either upward or downward due to greater or less activity in the center than at the side as is easily possible, then we have a condition of danger. For if the edges of the zone abut against a conical surface converging on the concave side of the curved pasty zone we shall have an arch formed which will tend to close up under the action of either the gas current or the stock column and obstruct the action of the furnace, perhaps even scaffolding it. But if the edges of the curved pasty zone abut against a cylindrical surface there is no "skewback" or support for such an arch and its chances of doing harm are much reduced.

CONDITIONS AFFECTING THE SIZE OF THE HEARTH

We can most conveniently consider the development of the size of the hearth from the chronological point of view.

In cold-blast charcoal furnaces, the earliest type developed, the hearths are extremely small, being only 2 ft. to 3 ft. in diameter for a corresponding bosh diameter of 8 ft. or 9 ft. In these furnaces the pressure of the blast is nearly always low so the shape of the gas column as affecting its resistance to the descent of the charge is less important than in furnaces with higher pressures. I am led to believe that this small hearth is necessary to obtain a sufficient concentration of heat to melt the iron and slag, for as shown by Fig. 1 on page 789 Vol. XIII (Nov. 1, 1915) these furnaces produce a very small amount of hearth heat per pound of fuel with their low critical temperature. Even with very high fuel consumption they are barely able to avoid freezing up, in other words their theoretical combustion temperature is but little above the free-running temperature of the iron and cinder.

In warm and hot-blast charcoal furnaces the theoretical combustion temperature is brought well above the melting temperature of the iron and slag, and the furnaces, therefore, are not forced to concentrate their heat in a very small space as is the cold-blast furnace. On the other hand, larger outputs are demanded of them, and this means a larger hearth in which to burn the fuel; it also means a greatly reduced upward batter of the bosh, and a much closer approximation of the hearth and bosh diameters to that required by a constant gas velocity.

In coke furnaces we go a step further in the same direction, hotter blast is used and more heat developed per pound of fuel. Therefore, we have a higher theoretical combustion temeprature and less need for concentrating heat in the hearth, much larger outputs are demanded and consequently a larger hearth is necessary to burn the fuel, while, owing to the higher temperature of the blast entering the hearth, the ratio of increase in volume at the top of the bosh is smaller and the hearth can therefore be relatively larger. This is the general line along which furnace development has actually taken place.

The concentration of heat in the hearth is a factor often ignored in modern practice although so vital to success in the cold-blast charcoal furnace, but in spite of this neglect it is a factor which must receive consideration when foundry and high silicon irons are to be made. We desire a high temperature of the iron so that it may take up a high percentage of silicon, and we are not at liberty to obtain this high temperature by making a limey, and therefore relatively infusible slag, because the lime would resist the entrance of the silicon into the iron. Some other way must therefore be found of securing a concentration of heat in making such irons, and this is done by making the hearth of relatively small diameter which gives a corresponding concentration of heat in that region with a comparatively small and therefore hot and active column of gas rising from it, down through which the iron must pass and be correspondingly heated on its path into the hearth.

CONSIDERATIONS AFFECTING THE DIAMETER OF THE STOCK LINE

The considerations affecting the diameter of the stock line are first, the relative volume of the gas there as compared to that at the top of the bosh, on the constant velocity theory; second, the swelling of the charge due to chemical action as it descends; third, the necessity of providing sufficient disengaging surface for the gas so that its velocity may be kept down and the carrying over of an excessive amount of the fine portion of the charge prevented.

The small gas volume of cold-blast furnaces causes little or no trouble by carrying over fine ore and fuel from the top of the furnace, and therefore the latter can have a relatively small area and the shaft of the

furnace can be given a rather sharp outwardly descending batter, 1½ in. to the foot, or even more.

The top diameter of warm and hot-blast charcoal furnaces is not increased as much proportionately as might be thought, for the smaller quantity of fuel used produces a proportionately smaller quantity of gas as compared with the total charge which it is required to heat up, the consequence is that most of the sensible heat is taken from the gas so that it is discharged from these furnaces quite cold, relatively speaking. I have seen top temperatures on a hot-blast charcoal furnace run for weeks below 212 deg. Fahr. The contraction of the gas due to this cooling offsets to a considerable extent the increased rate of blowing of such furnaces, and makes a relatively small stock line sufficient in this case also.

In coke furnaces using Mesaba ore the controlling factor in stock-line diameter is the velocity of the gas issuing from the surface of the charge. If this exceeds a certain rate fine particles of ore and other materials are picked up bodily and carried over with the gas current causing very serious inconvenience and loss in utilizing the gas and a loss of ore which is normally important and may easily become excessive.

If the output be great the gas volume must clearly be so likewise within narrow limits and the only way to reduce its velocity is to increase the area of the throat.

A. N. Diehl has stated that the surface of the charge in ordinary practice using a large percentage of Mesaba ore is constantly in agitation with particles rising and falling all over the surface and this is obviously the limit of gas velocity permissible.

The condition is precisely similar to that in a steam boiler where it has been found absolutely necessary to provide a given amount of disengaging surface for each cubic foot of steam produced under penalty of having the steam pick up and carry over such quantities of water as to make the operation of the boiler dangerous if not impossible.

This necessity of keeping within a certain limiting top velocity has exercised a potent influence on furnace lines, for the top diameter irrespective of all other conditions must be large enough to keep the issuing velocity below the danger line. I am inclined to believe that this consideration has forced the use of larger stock lines on hard-driven furnaces than other considerations demanded and that if we were satisfied to blow a little slower on a given furnace we could probably contract its stock line to the benefit of the operation as a whole.

In some ores the swelling action is slight and in others very great. In the experiments of O. O. Landig (*Trans. A. I. M. E.*, Vol. XXVI) some ores caused a deposition of carbon from CO five or six times the original volume of the ore, this being sort of a catalytic effect. The effect of such an increase in the volume of the ore tends to swell the whole charge and as it cannot secure more room above or below it must have room to expand laterally if it is not to become jammed in the furnace by this action. The furnace should therefore expand downward at quite a rapid rate to prevent the possibility of such jamming.

The diameter of the bosh being controlled by hearth and bosh conditions we are not at liberty to secure expansions by enlarging that and in consequence we have only one method of increasing this batter which is by carrying the stock line diameter of the furnace down as close as we dare to the point where the swelling of the charge begins or roughly to the bottom of the warming and drying zone, so concentrating the outward batter into a shorter zone and making it more rapid. This is the line along which the modern development of furnace lines has taken place. At the same time I have never felt perfectly sure that it would not be safe to increase the bosh diameter and so secure greater batter. It is worth noting also that too large a stock line defeats its own end, as far as keeping down flue dust is concerned, for nothing makes so much flue dust as irregular descent of the charge, "slipping," and if the furnace works "tight" in the zone of carbon deposition this will result in top slips and the production of much flue dust, while if the stock line be somewhat reduced the resulting increase in outward batter supplies more room for expansion and relieves the "tight" zone, so tending to reduce slipping.

CONSIDERATIONS AFFECTING THE BOSH DIAMETER

We have already seen that the diameter of the gas column at the top of the bosh for constant velocity is larger than the actual bosh diameters in common use and have indicated certain conditions affecting this, but the conditions are too many and too complicated and we do not know positively enough about them to permit drawing very definite conclusions. We do know that in earlier days boshes were very much larger, particularly in relation to hearth diameter, than they are now (see Fig. 7 and following) and the rapid batter of the shaft and flat bosh slope which resulted being continued until they intersected, with no intervening cylindrical section made rather a sharp internal angle where they met and it seems to be abundantly established by the experience of the furnacemen of that day that this was a very inactive region. Its area was so great that the gas velocity through it was very low; accordingly it was a fruitful zone for the establishment of scaffolds which might content themselves with filling up the useless space, but once formed, were likely to grow too large and were certain to be irregular so that their influence on the work of the furnace was generally, though not invariably, bad. In my own experience I have seen a furnace whose bosh was too large for the work it was doing and whose work was less satisfactory than smaller furnaces had been.

On the other hand, many furnaces were built about thirty years ago with extremely small boshes, only one-fifth or less the height of the furnace in diameter, and some of these have been built in recent years, but except on very hard and irreducible ores which swell very little during reduction, they work with high pressure and consequent hanging and irregularity, therefore with high coke consumption, and in general very unsatisfactorily.

It would seem, therefore, that while the diameter for constant gas volume may not be and probably is not the correct diameter for the bosh, it is not very far from it and is certainly closer to it than some actual bosh diameters which have been used, both larger and smaller. It is evident from the discussion of hearth and stock line diameters above that both of these must exert an influence upon the bosh diameter in the directions and for the reasons pointed out. It seems certain, therefore, that the bosh diameter must be a compromise resulting from these considerations and many others, notable among these being the height and angle of the bosh; for given these and the diameter of the hearth the diameter of the bosh obviously becomes absolutely determined, as a consequence we cannot change one of these three alone but must change at least two and this fact greatly increases the difficulty of determining the controlling conditions.

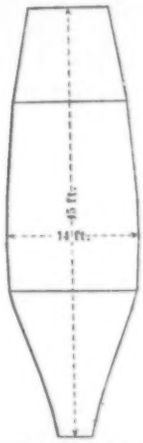
In a general way the necessity of more room for expansion for the charge in its descent and for the gas volume in its ascent through the bosh would seem to indicate a somewhat larger bosh diameter than is now customary, as none of the influences mentioned indicate

Blown-in, Mar. 15, 1844.
Blown-out, July 17, 1844.
Iron per week, tons, 52.29.
Average grade of iron, 1.68
Fuel per ton pig, tons, 2.28
Blast-temp., 500°-600°.
Blast-pressure, pounds, 4.
Number of tuyeres, 3.

FIG. 7—FURNACE NO. 1

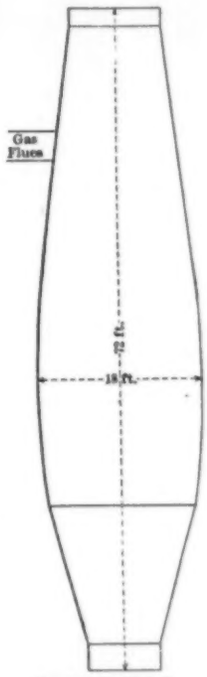
Blown-in, Sept. 5, 1844
Blown-out, May 16, 1846.
Iron per week, tons, 57.46.
Average grade of iron, 1.89.
Fuel per ton pig, tons, 2.04.
Blast-temp., 500°-600°.
Blast-pressure, pounds, 4.
Number of tuyeres, 3.

FIG. 8—FURNACE NO. 1



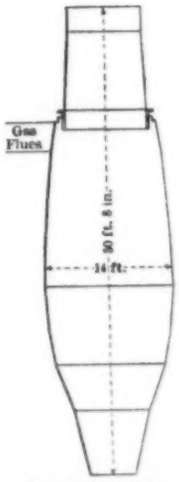
Blown-in, May 25, 1845.
Blown-out, Aug. 24, 1847.
Iron per week, tons, 68.36.
Average grade of iron, 3.27.
Fuel per ton pig, tons, 1.95.
Blast-temp., 500°-600°.
Blast-pressure, pounds, 4.
Number of tuyeres, 4.

FIG. 9—FURNACE NO. 2



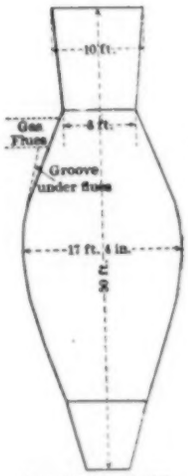
Blown-in, Jan. 7, 1869.
Blown-out, Feb. 28, 1871.
Iron per week, tons, 257.00.
Average grade of iron, 3.72.
Fuel per ton pig, tons, 1.35.
Blast-temp., 500°-650°.
Blast-pressure, pounds, 5.5-6.25.
Number of tuyeres, 7.

FIG. 16—FURNACE NO. 5



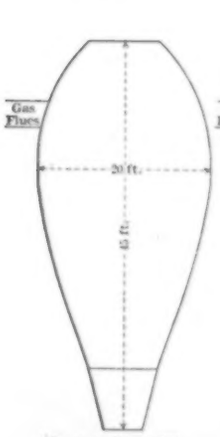
Blown-in, Nov., 1869.
Blown-out, Apr., 1873.
Iron per week, tons, 182.86.
Average grade of iron, 4.34.
Fuel per ton pig, tons, 1.59.
Blast-temp., 650°-750°.
Blast-pressure, pounds, 4.5-5.
Number of tuyeres, 4.

FIG. 17—FURNACE NO. 2

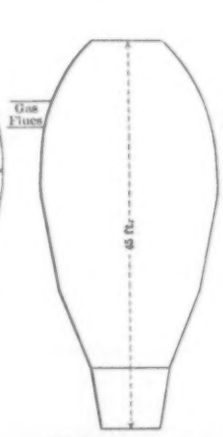


Blown-in, Aug. 22, 1869.
Blown-out, Feb. 6, 1871.
Iron per week, tons, 189.52.
Average grade of iron, 4.61.
Fuel per ton pig, tons, 1.46.
Blast-temp., 650°-750°.
Blast-pressure, pounds, 4.5-5.
Number of tuyeres, 5.

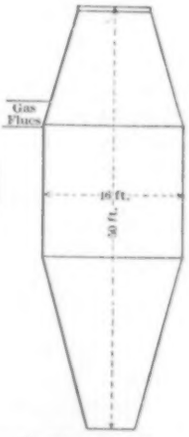
FIG. 18—FURNACE NO. 3



Blown-in, Mar. 2, 1851.
Blown-out, July 24, 1853.
Iron per week, tons, 114.04.
Average grade of iron, 3.42.
Fuel per ton pig, tons, 1.82.
Blast-temp., 500°-600°.
Blast-pressure, pounds, 4.
Number of tuyeres, 5.

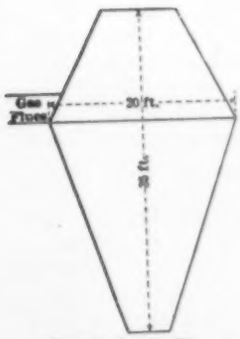


Blown-in, Sept. 20, 1853.
Blown-out, Mar. 28, 1855.
Iron per week, tons, 140.69.
Average grade of iron, 4.14.
Fuel per ton pig, tons, 2.03.
Blast-temp., 500°-600°.
Blast-pressure, pounds, 4.
Number of tuyeres, 5.

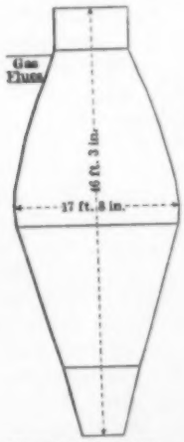


Blown-in, July 1, 1855.
Blown-out, July 1, 1857.
Iron per week, tons, 131.47.
Average grade of iron, 2.72.
Fuel per ton pig, tons, 1.91.
Blast-temp., 500°-600°.
Blast-pressure, pounds, 4.
Number of tuyeres, 5.

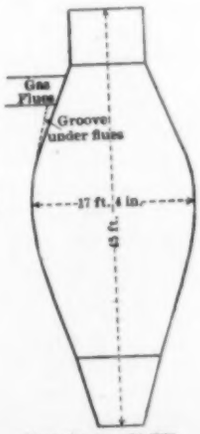
FIGS. 10, 11 AND 12—FURNACE NO. 1



Blown-in, Oct. 20, 1850.
Blown-out, Mar. 31, 1851.
Iron per week, tons, 103.96.
Average grade of iron, 3.34.
Fuel per ton pig, tons, 2.30.
Blast-temp., 500°-600°.
Blast-pressure, pounds, 4.
Number of tuyeres, 5.



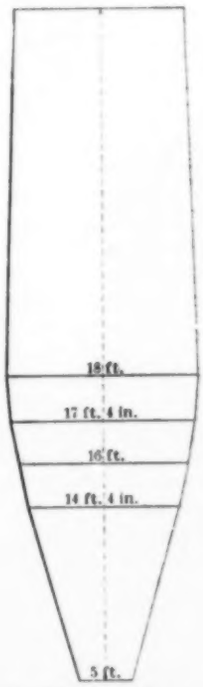
Blown-in, June 10, 1851.
Blown-out, Aug. 7, 1853.
Iron per week, tons, 109.22.
Average grade of iron, 3.97.
Fuel per ton pig, tons, 2.
Blast-temp., 500°-600°.
Blast-pressure, pounds, 4.
Number of tuyeres, 5.



Blown-in, Aug. 26, 1862.
Blown-out, Apr. 21, 1865.
Iron per week, tons, 154.69.
Average grade of iron, 4.19.
Fuel per ton pig, tons, 1.82.
Blast-temp., 500°-600°.
Blast-pressure, pounds, 4.5.
Number of tuyeres, 5.

FIGS. 13, 14 AND 15—FURNACE NO. 3

FIG. 19—FURNACE NO. 2 MUSCONETCONG IRON WORKS, STANHOPE, N. J., 1871



Blown-in, Jan., 1874.
Blown-out, Aug., 1874.
Iron per week, tons, 214.74.
Average grade of iron, 3.67.
Fuel per ton pig, tons, 1.52.
Blast-temp., 700°-800°.
Blast-pressure, pounds, 4.5-5.
Number of tuyeres, 5.

FIG. 20—FURNACE NO. 1

any danger from a moderate step in this direction, especially with the increasing hearth diameters now being used.

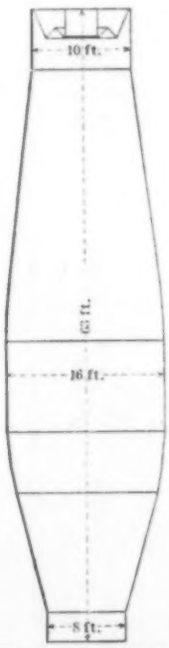
Of course, in so abstruse and difficult a matter the test of time and experience is the only safe guide.

The evolution of practice from the early days of the anthracite iron industry to its decline about thirty years ago is well shown by Figs. 7 to 22 from Mr. F. Firmstone's paper.

About a generation ago many furnaces were built with a small hearth, a high and very steep bosh, and a top much larger than the hearth. The evolution of standard practice at the two largest furnace plants in the country using Lake ores is well shown by Figs. 23 to 36, reproduced from H. A. Brassert's paper "Modern American Blast Furnace Practice" before the American Iron and Steel Institute in 1914.

The boshes have been lowered virtually 50 per cent, the hearth has been increased about 50 per cent, and the angle of the bosh has gone through a cycle swinging from 79 deg. down to 72½ deg. and now back again to 80 deg. The top diameters have been changed but little, as have the heights, practically all the later ones being 90 ft. These changes have taken place with an increasing rate of production, the net result of which has been to make an increased tonnage per furnace of three to one over the practice of a generation ago.

With this increased output has gone necessarily an increased volume of wind. The resulting increase in pressure has increased the rapidity of combustion and reduced the amount of space necessary for that operation, so that the zone of fusion and the top of the bosh have steadily fallen. To a certain extent it is proper to say that the blast heats available have increased and that therefore there is less relative increase in volume of the gas column at the top of the bosh as compared with that at the tuyere plane and this has coincided with the increase in the hearth diameter, as it should on the theory of constant gas velocity; at the same time it must be recognized that the desire to produce a greater tonnage per furnace with the consequent necessity of burning more coke, and affording more room for this, has been the chief cause for the latter change.



Blown-in, Aug. 19, 1877.
Blown-out, Oct. 30, 1880.
Iron per week, tons, 304.2.
Average grade of iron, 2.13.
Fuel per ton pig, tons, 1.15.
Blast-temp., 800°–850°.
Blast-pressure, pounds, 6.5–7.5.
Number of tuyeres, 5.

Same profile, Langen charger
Blown-in, Mar., 1881.
Blown-out, Apr., 1884.
Iron per week, tons, 340.2.
Average grade of iron, 3.01.
Fuel per ton pig, tons, 1.21.

FIG. 21—FURNACE NO. 1, REBUILT 1875-77

Blown-in, Aug. 5, 1882.
Blown-out, July 15, 1886.
Iron per week, tons, 412.4.
Average grade of iron, 2.75.
Fuel per ton pig, tons, 1.21 (one-eighth coke.)
Blast-temp., 800°–850°
Blast-pressure, pounds, 8–9.
Number of tuyeres, 7.

86 weeks unsized ore (1882–84):
Iron per week, tons, 349.5.
Average grade of iron, 2.53.
Fuel per ton pig, tons, 1.32.
118 weeks sized ore (1884–86):
Iron per week, tons, 458.3.
Average grade of iron, 2.88.
Fuel per ton pig, tons, 1.15.

FIG. 22—FURNACE NO. 2, REBUILT 1881-82

As to the considerations which effect the slope of the bosh, we know but little. At the beginning of the period covered by the set of profiles reproduced from Mr. Brassert's paper it was quite customary to use very small hearths and steep bosh angles in furnaces much smaller in maximum diameter in the bosh and also at the top than number 1 of this series. For a period of years and within limits it may be correctly said that a proportional increase of both hearth and bosh diameters took place, as it properly should on the theory of constant gas velocity, and this, combined with the lowering of the bosh, had the effect of greatly reducing the bosh angle. That this effect was highly beneficial in some cases, I have seen demonstrated so unmistakably as to leave no room for doubt, but now, as above noted, the tendency is to return to bosh angles of between 77 deg. and 80 deg., and with these angles it is possible to use high blast temperatures with large percentages of Mesaba ore, something it was considered impossible to do for many years, for a reason of which many furnacemen convinced themselves by trial, that furnaces using large percentages of these ores would "stick" if given more than a very moderate amount of blast heat.

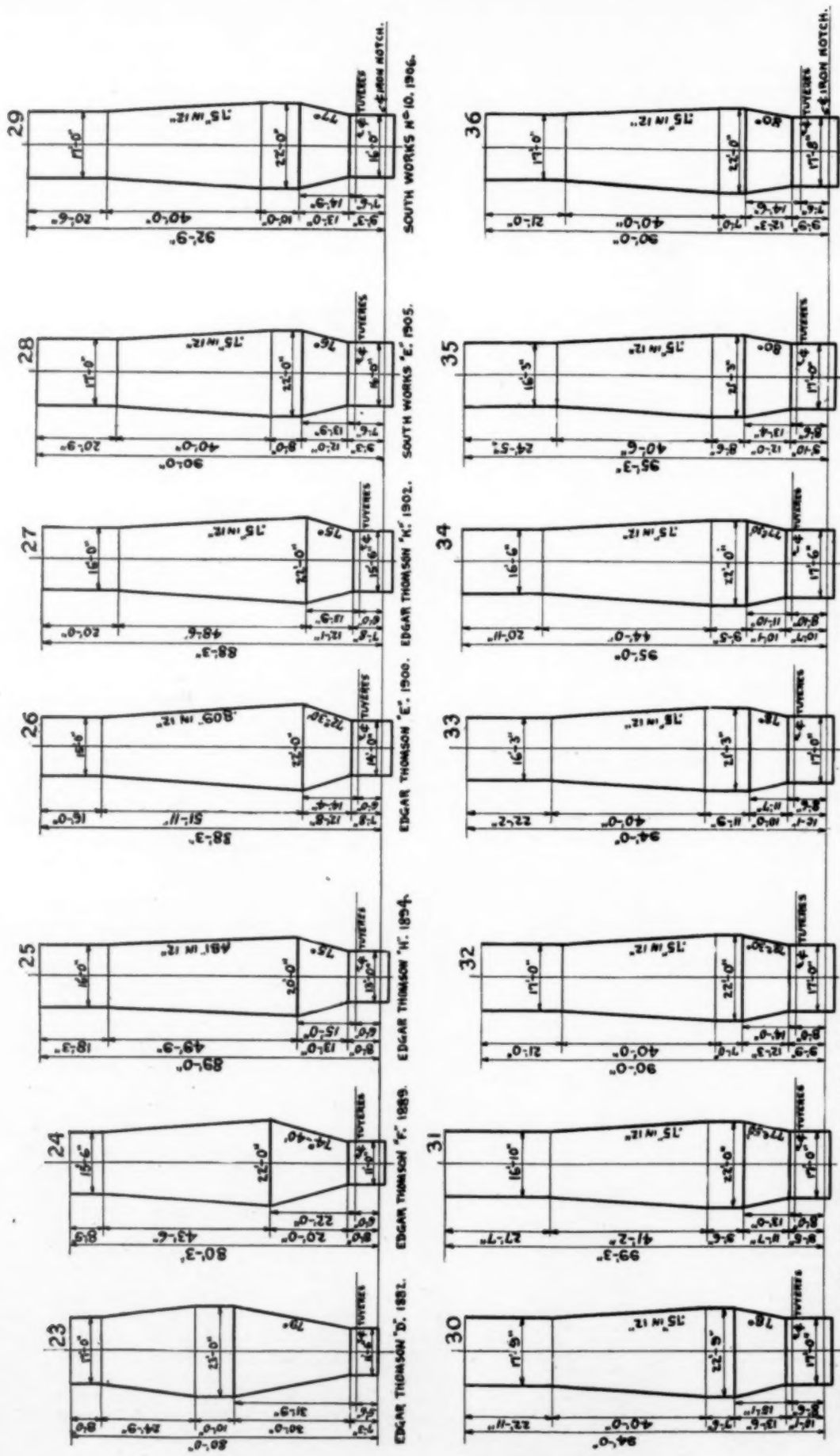
The reason for this action is not definitely understood as far as known to me. Presumably it results from the fine subdivision of the ore which, when in a partly reduced condition, enables it to form a plastic mass too early in its descent, if the furnace becomes too hot, and is analogous to the tendency of all furnaces irrespective of the ore they use to stick if they become excessively hot in the hearth.

Whatever may be the cause of this tendency it is now demonstrated that it may be overcome by steepening the angle and reducing the height of the bosh, presumably so as to furnish smaller resistance to the descent of the charge column and thereby counteract the tendency of the charge to hang from being sticky.

With the change in practice worked out at the South Chicago Works of the Illinois Steel Company, described in the papers of Messrs. Brassert and Mathesius, has gone an increase in the pressure-drop for penetration as mentioned earlier in this article. The increase is more than proportional to the hearth diameter through which it must act while the tuyeres used are very long, and it is probable that the resulting acute jetting action virtually builds up the inside of the hearth and on the lower portion of the bosh, owing to the effects described under the head of penetration.

Considering these two circumstances together it may be that the high penetration produces "phantom" bosh and hearth lines on which the furnace really works in operation, the bosh flatter, and the hearth diameter smaller than those provided in the construction and yet short and steep enough to prevent too great support of the stock by the bosh walls in the (upper) pasty zone, thus giving a certain amount of latitude in the working lines of the furnace, within which it may find those best suited to the conditions.

These views in regard to the South Chicago practice are intended merely to be suggestive, they must not



FIGS. 23 TO 36—SHOWING THE DEVELOPMENT OF BLAST FURNACE LINES FROM 1882 TO THE PRESENT TIME, AS ILLUSTRATED BY THE FURNACES BUILT AT THE EDGAR THOMSON WORKS, CARNEGIE STEEL COMPANY AND THE SOUTH WORKS, ILLINOIS STEEL COMPANY

be considered as established. It must be noted also that this change has been accompanied with an improvement in the quality of fuel used which has enabled practice to be followed which would not have been so successful with an inferior fuel. The concentration of heat with a poorer fuel is not sufficiently great in so large a hearth and a tendency would arise that might be very troublesome for the hearth to build up in the bottom. Even now it remains to be demonstrated that a sufficient concentration of heat in the hearth can be made with these furnace lines to produce foundry and other high-silicon irons, furnaces of this type having made their records on steel-making irons low in silicon, and having definitely failed to produce foundry iron satisfactorily in some cases.

Reviewing all these complex considerations many of them obscure and difficult to understand and all almost virtually impossible to measure, it becomes evident that the mechanical principles of the blast furnace are not second in practical importance to the chemical and thermal principles and that if furnaces are to yield a satisfactory commercial result we must consider with the utmost care not alone chemical equations and heat balances which often largely take care of themselves any way, but questions of regular and uninterrupted descent of the charge column, leading to low fuel consumption, low flue-dust loss and regular product, of low and uniform blast pressure permitting the use of small and inexpensive power plants and small consumption of furnace gas, and other purely mechanical questions.

It is a safe statement that if one-half the scientific research had been expended on these practical mechanical questions that has been spent on chemical equilibria and lopsided heat balances the science and art of furnace operation would be far ahead of where they are to-day.

The Production of Ammonia from Cyanamid

A paper read at the Baltimore meeting of the American Institute of Chemical Engineers on January 12, 1916.

BY W. S. LANDIS

After working for many years on the problem of the fixation of atmospheric nitrogen in the form of cyanides and cyanamids, Professors Frank and Caro of Berlin were forced by the outbreak of the Boer war to turn their attention to the utilization of their products otherwise than in the field of precious metal extraction. A consequence of the then existing economic situation was the discovery of the process of transforming the cyanamid compounds into ammonia. United States Patent No. 776,314, granted Nov. 29, 1904, most probably represents the first American publication on this subject.

According to the specifications of this patent various cyanamid compounds and derivatives, including the crude form of the calcium salt sold under the name of lime nitrogen, when treated with steam or water in the proportion of three molecules of water to two atoms of the nitrogen in the cyanamid salt, will yield ammonia. It is recommended in the specifications that the reaction be carried out at temperatures from 160 deg. to 180 deg. C. in a closed vessel, though the claims of this patent cover temperatures above 100 deg. C.

There has grown around this process and its later refinements in the last fifteen years an extremely important ammonia industry. Naturally the greatest development has been in Europe, its home, and it is only within the past year that a plant comprising full-size apparatus has been in operation in the United States. In attempting to catalog the various plants throughout the world which have been converting cyanamid into ammonia in large-scale operations, I find that available information, particularly since the outbreak of the European war, is so incomplete that the listing in consequence was very inaccurate. It is certain, however, that the transformation of cyanamid into ammonia is successfully carried out in Norway, Germany, France, Switzerland, Italy and Japan, and prior to the war in Belgium, the bulk of the product going into ammonium sulphate for the chemical and fertilizer trade. Norway is producing large quantities of ammonia used in the Birkeland-Eyde plants for the production of ammonium nitrate; France has produced considerable quantities of anhydrous ammonia by this process; at the present time Germany is producing enormous quantities of nitric acid from this cyanamid-ammonia by a newly developed oxidation process, and is erecting cyanamid plants equipped with ammonia apparatus at various places.

The fixation of atmospheric nitrogen, chiefly due to our Government's policy in respect to water power development, has not been practised in the United States. During the year 1914 contracts were let in Germany by the American Cyanamid Company for the equipment of the largest single ammonia plant then projected or operating in the cyanamid industry, but the outbreak of the European war interefered with the shipment of this apparatus, nearly all of which was seized by the German Government for the purpose of providing for its own explosive requirements. It was possible to bring only a small portion of this equipment over to the States, where it was set up and put into operation, and is now producing several tons of pure ammonia gas per day. This plant has been in continuous operation here for six months without any signs of trouble whatever, and is considered to be most successful and satisfactory in every way.

RAW MATERIALS

The crude cyanamid or lime-nitrogen is now a well-known commercial product. The Canadian factory supplying the United States and its insular possessions with this product has a capacity of fixing nitrogen equivalent to 90,000 lb. of ammonia per day, and with the completion of certain additions now being made will be capable of supplying some 110,000 lb. of ammonia each 24 hr. The demands for this product, most of which goes into the fertilizer industry, are so great that the plant is now operating at its full rated capacity. It is therefore evident that the supply of raw material for an ammonia industry is in no sense limited.

Crude cyanamid, or lime nitrogen, the reagent used for the production of ammonia, is an electric furnace product, whose production has been described elsewhere* by the writer. This material as turned out of the furnace, contains nearly 25 per cent nitrogen in the form of $CaCN_2$, 12 per cent CaO and 12 per cent carbon, with miscellaneous impurities derived from the various raw materials entering into its manufacture.

The other raw materials entering into the ammonia process are soda ash and hydrated lime. The quantities used are small, being approximately, 3½ per cent and 2 per cent respectively of the weight of lime nitrogen used. Steam and power requirements which vary with the size of the plant are discussed later.

CHEMISTRY

On treating lime nitrogen with steam, ammonia is produced from the calcium cyanamid according to the following reaction:

$$CaCN_2 + 3\,H_2O = CaCO_3 + 2\,NH_3$$

The reaction is almost quantitative when carried out

*Metallurgical and Chemical Engineering, vol. XIII, p. 213 (April, 1915).

on a large scale according to the process to be described later in detail. This reaction is exothermic in character, and while the exact heat of formation of calcium cyanamid has never been determined accurately, it is believed that the heat evolution from the decomposition of the cyanamid alone amounts to between 200 and 300 lb. cals. per pound of ammonia evolved. This plays an important part in the present method of carrying out the process, inasmuch as after once starting the reaction under proper conditions it will proceed of itself, and, in fact, with such great velocity that only complicated and highly developed apparatus can take care of the gaseous products.

The process as carried out in the plant operating in the United States is essentially that described in the specifications of United States Patent 1,149,633, dated Aug. 10, 1915, "Process of Making Ammonia from Calcium Cyanamid."

In order to take advantage of the exothermic character of the reaction, as above stated, the process is made to take place in an autoclave partly under high pressure. This apparatus consists of a steel tank approximately 6 ft. in diameter, 21 ft. high and capable of operating under a working pressure of 300 lb. per square inch. It is provided with a powerful stirring apparatus. Into this autoclave is charged about 12,000 lb. of mother liquor derived from a previous operation (fresh water to start), and lime nitrogen is slowly fed into this liquor under continuous agitation. As the lime nitrogen contains always a fraction of a per cent of undecomposed carbid, acetylene is evolved during this dissolving of the lime nitrogen. A proper ventilating system is provided to remove this acetylene at such dilutions as will be non-explosive even if subjected to a source of ignition. The charging is usually carried on over a period of an hour so as to insure a thorough incorporation of the lime nitrogen with the solution and the breaking up of all lumps in the slurry.

When the lime nitrogen has all been added to the autoclave the reagents—soda and lime—are added for the purpose of increasing the efficiency of ammonia evolution, principally through prevention of the formation of polymeric forms of cyanamid compounds which are difficult of transformation into ammonia. The autoclave is then closed up, and steam is admitted for approximately 15 min., or until the pressure gage on the autoclave indicates three or four atmospheres, which shows that the temperature in the autoclave has been raised sufficiently to start the reaction at a fair rate of speed. The reaction then proceeds of itself, generating ammonia and steam in the autoclave, and it is necessary to relieve this gas accumulation by means of

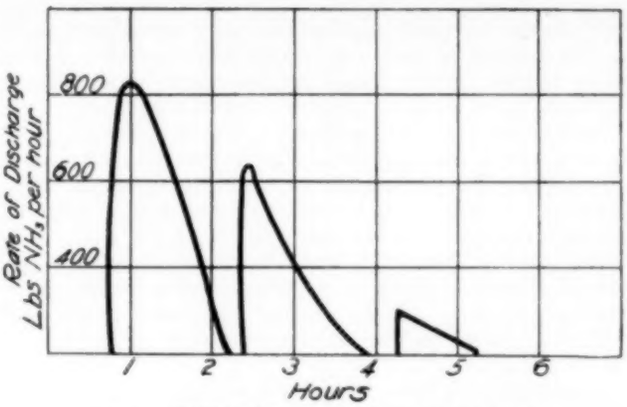


FIG. 2—VARIATION OF RATE OF DISCHARGE

suitable valves to avoid excessive pressures in the apparatus. The rate of reaction becomes cumulative as the temperature rises, and this relief of ammonia and steam must be permitted. Under normal working conditions the pressure in the autoclave will rise to about twelve or fifteen atmospheres in the course of about 20 min. with the relief valve open. The pressure then drops off slowly, as the gas is discharged, the rate of discharge being usually regulated by the attendant at the valve so as to maintain a constant pressure in the ammonia line, and at the end of about one and a half hours from the start of the operation the evolution has usually stopped.

Nearly all of the cyanamid in the charge has been decomposed during this first period of the operation, but the solution is still highly charged with ammonia, which it is necessary to expel. A very small amount of undecomposed lime nitrogen may be left, particularly of polymerized forms, which yield up ammonia only slowly. The steaming operation is then repeated, this time introducing steam until the pressure of the autoclave goes up to six to eight atmospheres. The ammonia discharge valves are again opened until the autoclave is discharged, requiring a period averaging approximately one-half hour for this second discharge.

In order to insure practically complete evolution of all the ammonia in the autoclave it is advisable to again repeat the steaming to six to eight atmospheres for a third period, discharging as before. During this last period of steaming and discharge rarely over 2 per cent of the total ammonia as charged is evolved, and it can, therefore, be omitted if extraordinary demands on the capacity of the apparatus are made.

Extended studies of the course of this decomposi-

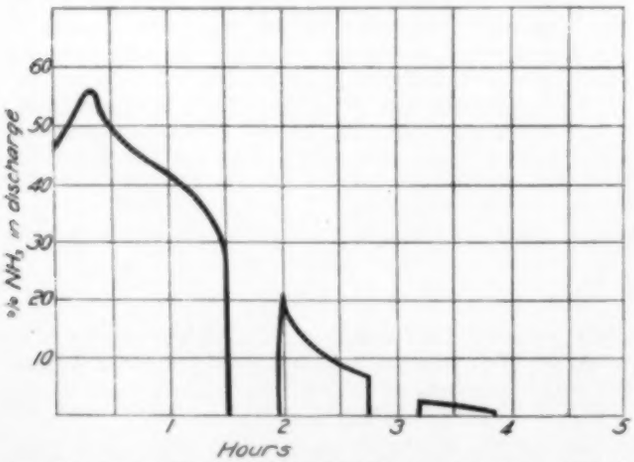


FIG. 1—VARIATION OF COMPOSITION OF AMMONIA--STEAM MIXTURE DISCHARGE

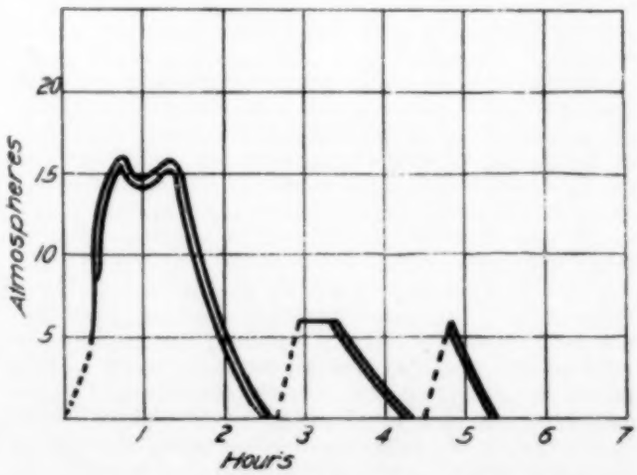


FIG. 3—VARIATION OF PRESSURE IN AUTOCLAVE

tion of lime nitrogen in the autoclave have been made both abroad and in this country, and are here reproduced in the form of charts. The discharge from the autoclave consists of a mixture of steam and ammonia, the composition progressively changing during the cycle. This variation in composition is shown for an actual operation carried out in this country in Fig. 1, in which the ordinates represent the percentage of NH_3 by weight in the ammonia-steam mixture discharged from the autoclaves, and the abscissa the time after start of the operation, analyses of discharge being made at approximately 3-min. intervals.

The rate at which ammonia is discharged from the autoclaves under operating conditions varies with the imposed condition. It has been found that most requirements are met by discharging at such rate as to maintain a constant pressure of steam and ammonia in the main leading from the autoclaves. Under such conditions the rates of discharge during a given operating cycle are represented by the curve in Fig. 2, in which the ordinates are the pounds of ammonia discharged per hour, and the abscissa again the various elapsed times from the start. In this case the charge in the autoclave was 7000 lb. of lime nitrogen analysing about 26 per cent equivalent NH_3.

Where a uniform supply of ammonia is required it can be obtained by the insertion of a special type of gasometer in the system. Also suitable grouping of a number of autoclaves and cyclical operation of the same will assist greatly in obtaining a uniform rate of production without the use of such gasometer.

In Fig. 3 is shown a curve of the pressures existing in a European autoclave, slightly smaller than the one described above, and operating on a charge of 8000 lb. of lime nitrogen. The dotted lines represent the admission of steam, and the full lines the pressures as shown on the gage on the autoclave. The ammonia discharge valves of the autoclaves are opened where the lines are indicated double.

At the close of the operation the bottom discharge valve is opened and the mud contained therein runs by gravity into large suction filters of the well-known "Nutsche" type. Here the liquor is sucked off from the solid constituents, a thorough wash with water is given and the sludge removed to the dump. Under normal operating conditions this sludge when dried contains less than 0.2 per cent of equivalent ammonia, and about 65 per cent of CaO in the forms of carbonate and hydrate. It is dark gray or black in color, due to the carbon present, and finds application as an agricultural lime. The liquor removed from the filter is used in dissolving the next batch.

HANDLING THE GAS

In the manufacture of ammonium sulphate, as carried out extensively abroad, the mixture of steam and ammonia coming from the autoclave is led directly into an absorber and produces a high-grade white sulphate. This production of sulphate is much simpler than from ammonia liquor. Where the introduction of the accompanying steam is not permissible, as in the production of certain ammonia salts which cannot be subjected to high temperatures, or where the process involves subsequent evaporation and crystallization, the ammonia-steam mixture coming from the autoclave is passed through a simple rectifying column provided with dephlegmator and condenser, and there is obtained therefrom a practically chemically pure ammonia gas, saturated with moisture at the temperature of the condensing water. This rectifying column is self-acting because of the large quantity of steam admitted with the ammonia-steam mixture, and requires no attention whatever in its operation other than to shut off the cooling water to the condenser when not in use.

The ammonia derived from the column, as before mentioned, is practically chemically pure, and is used directly in a large number of chemical industries. The Birkeland-Eyde engineers absorb this ammonia gas in distilled water, forming a dilute aqua ammonia, which they add directly to their dilute nitric acid for the manufacture of ammonium nitrate, the product being of extraordinary quality. On the other hand, ammonium nitrate of equal grade may be produced directly from the ammonia gases dehydrated in the column without the water absorption step.

One of the large autoclave plants in France has been manufacturing anhydrous ammonia for years, and in addition to the above purification system they have installed an oil washer, charcoal filter and lime-drying boxes before liquefaction. The oil washer, the writer was informed, was installed to remove some very minute traces of an unknown organic compound, but he has inferred that the character and quantity of this impurity, from the manipulation of this apparatus, is largely mythical.

For the production of nitric acid from ammonia, the product as taken from the condensers attached to the ammonia column is so pure that no trouble is occasioned by the poisoning of the catalyzers used in its subsequent oxidation.

COMPLETE PLANT

An autoclave plant* of 15 autoclaves, such as supplied the Birkeland-Eyde Co., which is similar to those intended for this country, has a rated capacity of 75,000 lb. of ammonia gas per day. The general arrangement of the apparatus, piping, etc., is clearly shown here by the use of colored inks, and I am sorry that photographic reproduction does not bring out the details of these drawings so that they can be shown in a more convenient form. Owing to the present inability to obtain this apparatus from Germany, where it has been manufactured on an extensive scale, the American Cyanamid Company has redesigned the whole equipment, adapting it to American standards and manufacturing conditions, and is now building this equipment in the United States.

EFFICIENCY OF DECOMPOSITION

An extended study made by the writer a year ago of one of the European plants which had been in operation for a long time, showed that the transformation efficiency of the nitrogen in the lime nitrogen into ammonia was over 99 per cent. Our American plant is showing operating efficiencies covering a period of several months substantially equal to the above.

AUTOCLAVE PLANT

An economical autoclave unit is one of eight working shells. As the operating load factor on these autoclaves is very close to 100 per cent it is not necessary to supply more than one spare shell to this eight autoclave equipment to insure a full 100 per cent load factor. Such a plant of eight autoclaves would require a 300-hp. boiler. It was the old practice abroad to set the safety valve on the autoclave shells at 20 atmospheres and operate the boiler at this same pressure. In our own designs here in the States we have successfully operated at 125 pounds steam pressure without trouble and can take steam from a common plant main. Superheated steam is preferable for the purpose, but not absolutely necessary. There is in addition required for operating the lime nitrogen feeding device, the stirrers in the autoclaves, the vacuum pump and the air compressor, and miscellaneous sludge disposal equipment a continuous motor load of approximately 100 hp. (the connected

*Drawings of this plant were exhibited by the author at the meeting.

motor load would probably average about 200 hp., depending upon local conditions).

Operating Costs

In the compilation of a cost sheet for the production of ammonia from lime nitrogen there is such great latitude in unit costs concerned that the writer is presenting rather full quantitative data, to which he is appending assumed unit costs. In most cases the assumed unit costs are averages existing before the outbreak of the European war, and to which an approximate return may be expected after its close. In any case they may be readily corrected to meet local conditions.

Lime nitrogen: 26 per cent ammonia. It is unquestionably the cheapest source of nitrogen (ammonia) in this country. The sales prices are dependent to an extent upon the quantities and deliveries contracted for. The freight is allowed at $3.00 per ton of lime nitrogen shipped in special containers, which should cover the greater portion of territory in the United States lying within a 500-mile haulage radius of Niagara.

Caustic lime is to be air slacked on spot, 2 per cent weight lime nitrogen used assumed at $6.00 per ton delivered.

Soda ash 3½ per cent of weight of lime nitrogen at $16.00 per ton delivered.

Power, 100 hp. continuous at 1c. per hp. hour.

Steam at 30c. per 1000 lb., 60 per cent weight lime nitrogen.

Water, 2 U. S. gal. per lb. ammonia. As the larger part of this is used in condensers and coolers the greater proportion may be salt water. Assumed at 2c. per 1000 gal.

Labor and superintendence: Assumed at 300 men hours per day at 30c. per man hour.

Repairs and renewals: $1.50 per ton ammonia, a record of long-time operations.

Interest: Assumed at 6 per cent on plant cost of $120,000.

Depreciation: On plant cost of $120,000 depreciated in ten years, say, 8 per cent.

Operating Cost of Ammonia Plant

Capacity 30,000 lb. ammonia per day, gas saturated with water at cooling water temperatures.

Item	Quantity	Rate	Per Day	Per Pound Ammonia
Freight	.....	$3.00	$180.00	$0.00600
Lime	1.20 tons	6.00	7.20	0.00024
Soda	2.10 tons	16.00	33.60	0.00112
Power	2,400 hp. hr.	.01	24.00	0.00080
Steam	72 M lb.	.30	21.60	0.00072
Water	60 M gal.	.02	1.20	0.00004
Labor	300 men hr.	.30	90.00	0.00300
Repairs and renewals	.....	....	22.50	0.00075
Interest	.....	....	20.00	0.00067
Depreciation	.....	....	26.66	0.00089
Miscellaneous	.....	....	24.67	0.00082
Total conversion cost, excluding NH_3 losses			$451.43	$0.01505

Cost of Plant

On account of the varied building conditions existing throughout the country it is almost impossible to give a detailed estimate of the cost of plant. A recent projection of such costs made by this company for a plant of this size, from which I have deducted the cost of land, foundations and sludge disposal, shows that an ammonia plant of the size herein described could be erected for about $120,000. This plant is designed to produce an ammonia gas as its final product cooled to the temperature of the available water of the condensers, and, therefore, not strictly anhydrous. This figure further assumes that water and power are furnished the plant, and no provision is made for power or pumping plants.

Steel buildings with corrugated iron sides and roof, and of a type which have demonstrated themselves as fairly satisfactory for this service are included. The limitations imposed by building laws and choice of architecture may force one to materially modify this estimate, as cheaper forms of construction may be used. On the other hand, many may prefer a more elaborate type of building than provided in the above estimate, which would materially raise this figure.

Summary

The large number of installations operating with perfect success in various parts of the world for a number of years have demonstrated the commercial possibility of making ammonia from lime nitrogen. The plant in its present highly developed state is extremely certain in its action and simple to operate. The efficiency obtained in the transformation of the nitrogen in lime nitrogen into ammonia gas is upward of 98 per cent, or almost quantitative. The consumption of reagents is remarkably small, and they are cheap and easy to obtain in almost all parts of the world.

The quality of the ammonia produced by this process is not surpassed by any in the United States. It is chemically pure as produced and requires no further costly and tedious purification to render it available for the highest grade chemical products, or for the production of liquefied anhydrous. The actual cost of production of this high grade pure ammonia on a considerable scale, which enables one to take advantage of the lower prices at which lime nitrogen is offered, brings high grade cyanamid-ammonia into the market almost as cheaply as the more impure forms already found there, and very much cheaper than it is possible to obtain an equal quality of ammonia from gas-house liquor, the coke ovens, etc.

American Cyanamid Co.,
Niagara Falls, N. Y.

Non-Ferrous Metal Market

Copper—According to the Geological Survey the copper production for 1915 was the greatest on record. The smelter production is estimated at close to 1,400,000,000 lb. The average price for the year was about 17.3 cents as compared with 13.3 cents for 1914. At the present time no one but the producers knows how scarce the metal really is. Since our last report the price has risen from 21.75 to 24 cents although no enormous amount of buying has been recorded. The last quotation was 24 cents on Jan. 12.

Tin—Imports for the year 1915 from all sources according to the New York Metal Exchange were 47,835 long tons as compared with 40,887 long tons in 1914. The average price for the year was 38.66. During the last two weeks the market has been excited and spot tin and early deliveries have been difficult to buy. The price advanced from 39.12½ on Dec. 28 to 44.75 on Jan. 5 since when it has reacted to 41.25 to 41.50.

Lead—The production of refined lead in 1915 according to the Geological Survey estimate was 565,000 tons as compared with 542,122 tons in 1914. The maximum price was 7.56 cents on June 14, the average for the year being 4.7 cents as compared with 3.9 cents in 1914. During the last two weeks three advances have been made by the Trust. On Dec. 31 the price was advanced to 5.50 on Jan. 4 to 5.75 and on Jan. 7 to 5.90.

Spelter—The estimated spelter production for 1915 was 492,495 short tons as compared with 362,361 short tons in 1914. The market during the last two weeks has been quiet but firm, with prices practically unchanged at 17.42½ to 17.67½.

Other Metals—Aluminium is quoted at 54 to 56 unchanged. Antimony is scarce and is quoted at 42.50. Silver is quoted at 56½. Quicksilver has risen to $175 per flask.

The Grading Industries

BY EDWARD S. WIARD

I have given the above title to certain industries, not because grading is the essential operation in them, being in most cases but an auxiliary one, but rather to discuss under this convenient title some mechanical problems which arise in industries in which grading is one of the necessary steps. Before the completion of the articles it will be seen how great is the scope of the "grading industries" and how much of interest there is in their history, statistics, technology and trade. The plan of the articles will be to describe first the "tools" used in grading. Following this portion of the articles, which will take up the theory of the action of grading devices and practical considerations governing their design and the kind of material for which they are especially suited, the grading industries will be taken up in alphabetical order.

The word "grading" is used in these articles in the sense of preparing material according to size or sizes, and in the majority of the grading industries the sizing is the finishing operation, following which products are ready for the market. In many cases they are ready for the consumer and in the rest they are ready for the initial operations of other industries. The majority of the grading industries have to do with the preparation of raw material which reaches the consumer indirectly through its use in other arts and manufactured products. Sulphur used in many arts and talc employed as a filler for wallpapers, for talcum powder, etc., are examples of graded products which reach the consumer indirectly. As examples of graded products which directly reach the consumer may be mentioned black gunpowder, flour and food products of many kinds, such as rice, peas, beans, coffee, etc. In the case of food products grading is done primarily to please the eye and to a minor degree for sanitary reasons. Crushed seed and fruit would invite decay. In the case of peas and beans uniformity of size also makes for uniformity of cooking.

Distinctions in Grading

In the subject of grading, distinction must be made between the breaking up of a granular or fragmental mass or masses of objects of the same or nearly the same general shape into a number of sizes, and the mere splitting of such masses into two, one fine and the other coarse, one or both being saleable but usually only the finer one. Where the fine material is the merchantable product the coarser part is either allowed to go to waste or, as is most commonly the procedure, it is subjected to comminution to obtain a complete yield as a fine product. This is usually done continuously; that is, the comminution means are closely connected with the separation means, the reject of coarse material from the latter flowing directly back to the comminuting devices. This mode of operating produces what is known as a "closed circuit," and what this means and its effect on the rate of feeding of the comminuting device is described in the reference below.[1]

Examples of splitting grading can be found in the preparation of talc for paper filling and talcum powders, flour, artificial and amorphous graphite for pencil making and high-grade lubricants, pumice for scouring-soap powders, infusorial earth for incorporation with high explosives, separation of sand and slime in the cyanide process for gold extraction, preparation of pigments, etc. Some of the modes of effecting the splitting are by dry screening—flour, pumice and sulphur being examples of this mode of separation; by air separation—natural amorphous graphite and pigments being examples of this mode of splitting. In both of these cases separation and comminution go on continuously, the end result being to reduce all the material treated to a finely divided saleable product.

In some industries the employment of a splitting grading or separation would yield a superior product, but the expense attending the use of separating means would be out of proportion to the value of the better product obtained. Again the possible means which could be employed would not be efficient, or the most effective process which could be employed would spoil the product made. In preparing feldspar for pottery purposes or abrasive soaps the finishing grinding is done in a tube mill. For the first purpose the spar is ground from four to six hours, when over 96 per cent will pass a screen with 200 openings to the linear inch. For soap purposes the spar may be ground for as long a period as ten hours. In these cases it must be evident that while a very finely divided product is desired there must be a large proportion of the spar which is ground unnecessarily fine in order to be sure that no grit remains in the finished material. If the spar were submitted to a water separation the fine material would have to be dried and it would be spoiled by caking. Efficient dry separation processes would not be applicable because of their expense and limited capacity. The best ground feldspar is worth about ten dollars per ton.

In the manufacture of Portland cement the use of a wet separation method would, of course, be out of the question, and dry separation by air would not be applicable for the reason stated above. As in the case of feldspar much material must be ground unnecessarily fine to be sure that all the product will be reduced to the proper limiting size which, in the case of cement, means that 75 per cent or over must pass a 200 mesh sieve. Portland cement has sold as low as $0.65 per barrel weighing about 380 lb. How fine a cement particle must be ground has not been definitely fixed by experimentation but there is no doubt that there must be a certain sized particle below which in point of size all the particles are cementing material and above which they are not.[2]

An unusual separation occurs in the shot-making in-

[1]Theory and Practice of Ore Dressing. Wiard. p. 203 et. seq.

[2]The available data on this point will be discussed later.

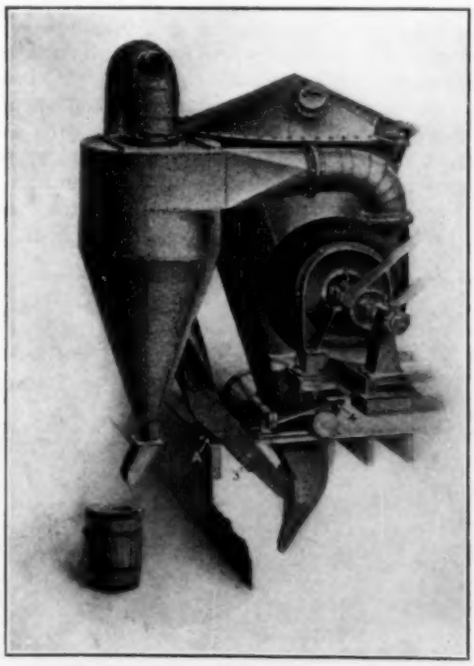


FIG. 1—VACUUM SEPARATOR

dustry. The superior rolling quality of the more perfectly rounded shot is taken advantage of in separating the perfect from the imperfect shot. The ungraded material is fed to a conical revolving surface at one point near the top of the cone. The more perfect shot will roll almost directly down to a discharge point along the edge of the cone which is almost directly below the feeding point, while the imperfect shot will roll more slowly and under the additional influence of the rotation of the conical surface report at points ahead of that where the perfect shot discharge.

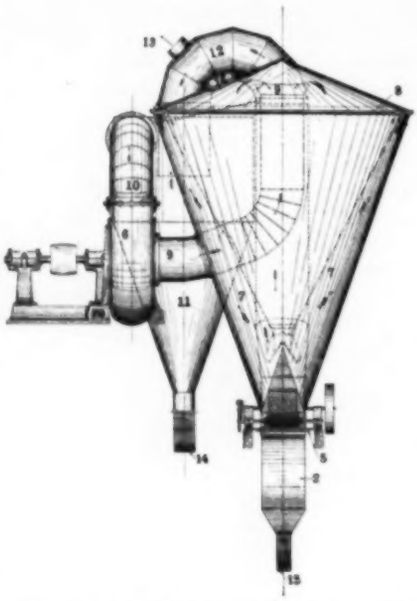


FIG. 2—SECTIONAL VIEW OF VACUUM SEPARATOR

Methods of making a series of gradings by fall of particles in currents of air, water or other fluids are described at a later point in the articles. This method of grading may also be employed to effect a splitting grading or separation. If air is used, large dust chambers will be required to settle the fine dust.

Grading by Air Separation

The Raymond air-separation apparatus is shown in Figs. 1 and 2. The material is fed in by an enclosed hopper at point 4. It is then drawn up between the inner and outer cones 7, the sectional area of the passage increasing toward the top or deflector 8. Between this point and the down-draft pipe 9 most of the coarse material will fall back and return to the comminuting device if one be provided below the feed point 4. The fine particles pass through the fan 6 and then through the collector 11 where the current of dust-laden air is given a centrifugal spin and drops the bulk of the finely divided material which can be collected at point 14. From the separator the air returns to point 4 by way of passage 3. It will be seen from this description that the device requires no dust chambers, for the air current is in a closed circuit and is used over and over again. While the air current returning to the feeding device may contain some fine material, this can be largely obviated by collection chambers of the proper size and regulation of the volume of air forced through the apparatus. Some regulation can be gotten through the wind gate *A*, Fig. 1. The Raymond apparatus is excellent for producing limited tonnages of impalpable powder. It is much used for preparing finely powdered drugs, pigments, graphite, etc.

Examples of Grading Incorrectly Termed "Classifying"

In the cyanide process for gold extraction and in a number of Western ore mills various forms of splitting grading devices are used to which the name classifier is wrongly given. The principal machines of this type are the Dorr, Akins and Federal-Esperanza, illustrated in Figs. 3, 4 and 5 respectively. In all these machines the material is fed in, mixed with a certain proportion of water, the amount of water being about six parts by weight of water to one of ore. If the amount of water coming to the classifiers exceeds this ratio it is properly reduced in Western practice by suitable dewatering devices. In cyanide mills either the Dorr or Akins type is used. The Federal-Esperanza classifier has been used to some extent in Western concentrating mills. Table I illustrates the capacity and work of the three classifiers.

TABLE I

	Akins	Dorr
Ratio water to ore	5.11	4.62
	Per Cent	Per Cent
Dry ore	16.38	17.64
Water	83.62	82.35
Tons, 24 Hours:		
Solids	92.76	76.20
Water	473.21	355.75
Sizing Tests		
Material Fed		
	Per Cent	Per Cent
On 20-mesh	1.5	1.5
On 40-mesh	10.0	13.5
On 60-mesh	14.0	15.0
On 100-mesh	13.0	12.5
On 200-mesh	17.0	15.0
Through 200-mesh	44.5	42.5
Sand Delivered		
	Per Cent	Per Cent
On 20-mesh	1.6	2.7
On 40-mesh	22.8	26.5
On 60-mesh	35.2	29.5
On 100-mesh	24.4	20.5
On 200-mesh	11.6	14.8
Through 200-mesh	4.4	6.0
Moisture	26.8	30.5
Slime Delivered		
	Per Cent	Per Cent
On 100-mesh	4.0	2.8
On 200-mesh	18.0	16.4
Through 200-mesh	78.0	80.6

Federal-Esperanza

Mesh	Material Fed. Per Cent	Sand Delivered. Per Cent	Slime Delivered. Per Cent
On 40	7.4	15.1	...
On 60	9.8	20.2	...
On 80	8.3	15.9	...
On 100	1.4	2.6	0.5
On 150	21.4	31.3	5.7
On 200	1.6	1.9	1.0
Through 200	50.0	13.0	92.0

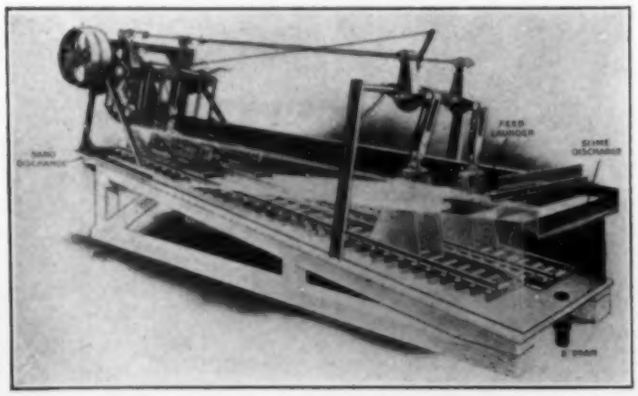


FIG. 3—DORR CLASSIFIER

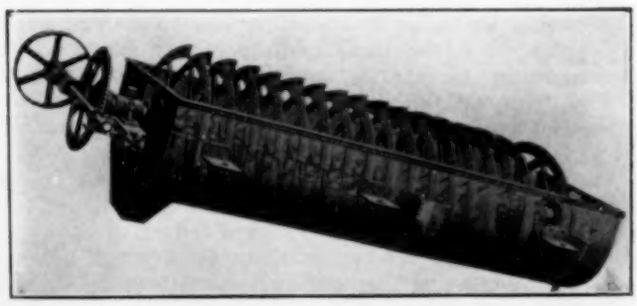


FIG. 4—AKINS CLASSIFIER

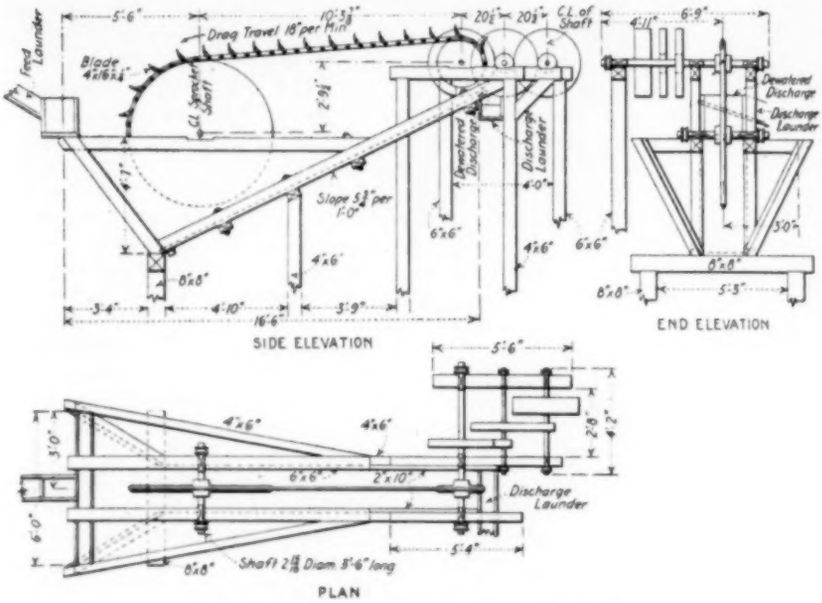


FIG. 5—FEDERAL-ESPERANZA CLASSIFIER

The figures in the case of the Dorr and Akins are comparative, having been made in the same mill and on the same material.

The Dorr classifier, as a glance at the figures of this machine will show, uses a flight-pushing device. On the upward or push motion of the blades they dip into the sand, and on the return motion they are raised above the sand. The advancing means of the Akins is merely a double spiral which is open in the center to allow the water and slime to drain back. The Federal-Esperanza classifier is an endless belt to which are secured flights or vanes. The speed of the belt is from 15 ft. to 30 ft. per minute. The capacity of the individual flight is about 0.2 lb. per square inch of flight surface.

The power required for driving any of the machines does not exceed 0.01 to 0.02 hp. per ton of the dry material treated daily. Considering all the merits and demerits of the three types there is not much choice for excellence among them. If the Federal-Esperanza be in first-class condition with the conveyer chain properly drawn up so that it does not drag upon the bottom of the tank it should show the smallest power consumption of the three, followed by the Dorr and the Atkins; that is, the unit power consumption or consumption per ton of sand delivered. The wear of the conveyer chain from grit may, however, cause it to drag upon the bottom of the tank, materially increasing the power consumption.

More capacity can be gotten from the Federal-Esperanza type for the area of individual blade employed since the conveying operation is continuous. In the case of the Akins, capacity for any particular size of spiral is limited by the fact that if it is run at too great a number of revolutions it will merely slide through the sand and not push it ahead.

In the matter of attention to lubrication and general oversight to see that the machines are functioning properly, the Akins machine should require the least attention and the Dorr the most.

In the matter of wear and tear of the rakes or moving means, the Akins will report the most, and between the Dorr and Federal-Esperanza there will not be much to choose.

In the matter of starting up after flooding and with the tanks full of sand it will be found that the Akins may often be started without digging out, while with the other two kinds this operation will be necessary.

The Dorr machine is provided with a device for raising the rakes before shut-downs but if the machine is flooded unexpectedly this device will not be of much use.

In the matter of cleanness of products the Akins delivers the cleanest sand product and the Federal-Esperanza the most contaminated one, but there is not much to choose in this respect between the Akins and the Dorr. The Federal-Esperanza delivers the cleanest slime of the three, the Dorr being the poorest in this respect, though there is but little practical difference between the Dorr and Akins on this point.

The Federal-Esperanza type is the oldest of the three and before this device was put upon the market Western millmen had made use of similar forms. The principal improvement of the Federal-Esperanza design is the use of a sprocket wheel of sufficient diameter that its bearings may be carried well up above the water and grit in the tank below. In the manufacture of white lead a classifier similar to the Federal-Esperanza had been in use for many years prior to the advent of this machine for separating the uncorroded portion of the buckles following the corroding and grinding operations.

The most interesting grading operations from a technical point of view occur in those industries where it is necessary to split a mass of material into three or more sizes. Grading of this kind can be done according to diameter or some other linear measure, or two linear measures; as, for example, in the grading of disks of varying size and thickness, by volume, by gravitation in fluids or by weight.

Necessity for Grading in Certain Industries

Some reasons for dividing a loose or broken mass of material into a number of sizes will be gathered from the following examples of the need of this operation in

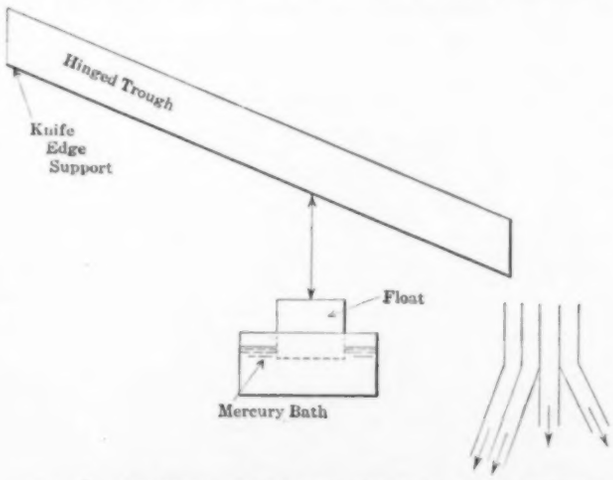


FIG. 6—MERCURY FLOAT FOR GRADING BY WEIGHING

certain industries and uses. In the use of abrasives the aim is to produce a smooth or polished surface from a roughened one. To gain time the roughened surface must be reduced progressively by abrasive grains whose diameter is roughly proportional to the depth of the projections of the roughened surface. Quite evidently, while the abrasive grains are tearing or breaking away the projections of the surface, they are grooving the smoother portions to an amount proportional to the size

of grain used, though to a lesser degree. On this account, if the ultimate aim is a smooth or polished surface, the abrasive must be used in graded masses starting with a coarse size and ending with a fine.

For human and animal consumption salt is graded to obtain varying rates of solubility. For household use a quickly dissolving product is desired, while for layering meat the salt is desired in a condition where it will dissolve slowly. This requires that household salt be finely divided and yet not so finely powdered that it loses its crystalline character, and in a damp climate becomes caked in the receptacles for holding it. If fine salt were used for preserving meat it would quickly dissolve in the moisture of the flesh and run to waste permitting the entry of decaying agencies. A very coarse salt is consequently used for layering meats, intermediate sizes between this and the finest being used where greater rates of solubility are desired.

Coal is almost entirely graded because of the household demand that this material be so delivered. It is quite evident that the limited size of household fireboxes will preclude the use of very large masses of coal. Again the limited height of household chimneys, or what is the same thing, the low velocity of the draft, forbids the use of much fines in the coal since it reduces the velocity of the gases in passage from the hotter part of the fire to the colder. On the other hand the surface exposed to the gases increases as the size of the particle decreases. For household purposes the best mean between long, crooked, narrow interstitial passages and area of pieces exposed to inflaming gases is somewhere between 1-in. and 4-in. pieces. If a quick fire is desired the best size will be somewhere near the lower limit of size. If it is desired that the fire burn to a bed of glowing coals and that the fire remain in this condition the greatest length of time, then a coal nearer to the larger size given will be selected.

The technology of grading by the use of screens and the means for obtaining volumetric grading will be left to the end of this section, and miscellaneous methods of grading will be taken up first, followed by modes of grading by fluids.

Miscellaneous Modes of Grading

U. S. Patent 1,080,088, Dec. 9, 1913, is for means of separating shrunken and discolored beans from perfect white beans. In this patent means are provided for bringing the beans singly to a position in front of a hinged spout. Means are provided for reflecting all the light from the beans on a selenium cell which consists of narrow strips of selenium joining broad brass plates forming portions of an electric circuit. If the hinged spout be supported by a magnet which is part of the selenium cell circuit, then when the perfect beans pass through the apparatus, since the resistance of the circuit will be diminished from the greater light impinging on the cell, the spout will be raised to the highest point and if a receptacle is placed in the proper position below the edge of the spout, the perfect bean will fall into it. If receptacles are placed behind the first one a gradation can be obtained from perfect to dark, shrivelled beans. According to Adams, greenish yellow rays lower the resistance of selenium the most. The device described or something similar may offer a means of grading according to color, and perhaps of separating ore from gangue.

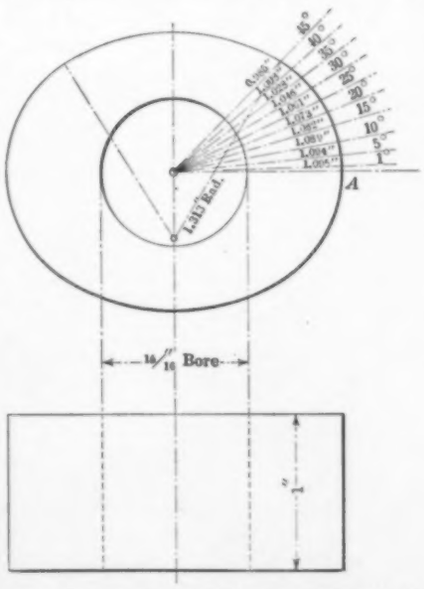


FIG. 7A—SINE BLOCK FOR GRADING BY WEIGHING

A silk-sorting machine is one for grading threads of silk according to thickness and winding them upon the proper bobbins. The proper bobbin is presented to the thread by the action of a lever which is governed by the thickness of the thread passing between gage-rollers.

Grading by weighing is only adapted to relatively large individual pieces. Each unit of such a device must have means for feeding the individual masses singly, and the interval of time must be sufficient to completely weigh and dispose of a piece before another passes over the grading means. The transportation element must not influence or interfere with the weighing element. A simple mode of obtaining grading by weighing would be to have a spout hinged at one end and supported by scale-beam connections at the other. Either of the devices shown in Figs. 6 and 7 would furnish the proper weight-opposing thrust Fig. 6 being a mercury float and Fig. 7 a sine curve weight-opposition, the spout hanging from or being supported by a strap or arm in contact with the curved surface which is at point *A* when the device is at the no-load position. With either of these devices means are provided for giving equal angular depressions of the spout for equal increased increments of weight. As with the selenium-cell device, if suitable receptacles be placed at the proper position below the hinged trough they will receive masses of equal weight.

Grading by Blowing

In grading by blowing, the air most commonly is introduced at the feeding point and from this point the air is expanded into a chamber of increasing cross section. The air may also be exhausted at the end of such a chamber, particularly if the very fine dust at the end of the chamber is to be forced through a dust collecting device. At regular intervals in the expansion chamber, gates are placed to receive the gradings which will, of course, be of a size inversely proportional to the cross section at any point. These gates are usually held to place by a lever and weight. When sufficient material has collected in the pocket above the gate to more than counterbalance it, the gate will open and permit the grading to discharge. Gates of this kind are, of course,

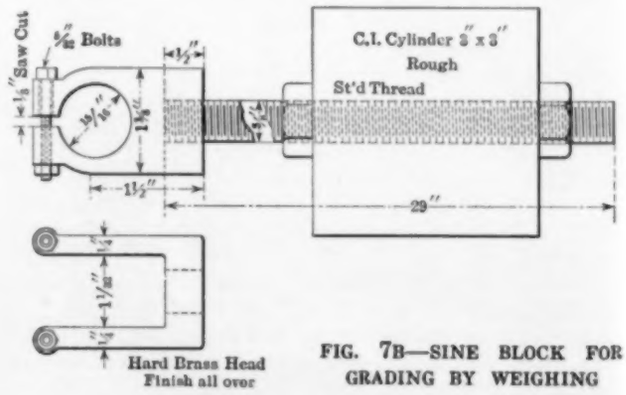


FIG. 7B—SINE BLOCK FOR GRADING BY WEIGHING

necessary to prevent the air from passing through the discharge passages, taking with it material which does not belong at this point.

Expansion chambers can be placed horizontally, on an inclination or vertically; in the last case consisting of a series of expansion chambers placed one above the other, the sizes increasing from top to bottom.

The vertical arrangement is the best from the theoretical point of view, but it has the disadvantage of requiring more head room than the other forms. With the vertical forms the air has the power to balance a grain of a particular size or weight, the balance being dependent upon the velocity, and this in turn upon the initial velocity created by the fan, and the area of the cross-section at the point of balance.

Grading by horizontal and inclined forms of chambers depends upon the transportive power of the air current, and the question as to whether a grain of a particular size will alight in the appropriate pocket depends not only on the transportive power of the current, but also the position of the grain in the current. If well above the discharge pocket into which it should discharge, it will fail to report in it and will be carried ahead. Also, if the grains which are reckoned too small to report in the pocket are in the current just above it, they will fall into it.

Air-grading is very little practiced to-day, for the settlement chambers required are very large as compared with settlement chambers for a heavier fluid such as water. If the material being graded permits of the use of water, this undoubtedly should be employed in preference to air. It is impossible to prevent strong cross-currents and eddies in the expansion chambers and this confuses the grading, making it quite markedly inferior.

A certain amount of fine dust is bound to cling to the walls at all points of the expansion chambers and this will contaminate the gradings.

There is no technology of this type of apparatus. In the vertical forms of apparatus, if the velocity of the air from point to point is known, as it can be, knowing the fan velocity discharge, it would be possible to calculate the size grain that the air current would balance. The pressures created by air velocities have only been calculated for large surfaces, and, as is well known, the smaller the surface the less does the unit pressure become.

In the inclined forms of chamber, the pressure of the air current is balanced against the inclined component of gravity less friction of the bottom of the chamber.

For horizontal expansion chambers of regular form, truncated pyramids or cones, the path of a particle in the feeding plane may be calculated theoretically from the following formula

$$y = \frac{x^4 A^2 g}{4A_1^2 L^2 V^2}$$

where A is the area of the small end of the chamber, A_1 the area of the large end, L the length of the chamber, V the velocity of the current in feet per second at the entry of the blast into the expansion chamber, and g the constant of acceleration.[3] The axes of the curve are taken through the center of the particle just as it enters the expansion chamber, and, of course, values for y are negative and for x positive.

I have some information to the end that air-grading is used for separating chicken feathers into various sizes. In the dry process for mica, air-grading is still used to some extent, but there are so many secrets in this industry that it is impossible to determine how the air-grading is done.

Grading by Projection

Some attempt has been made to grade material by the varying trajectory when thrown from the surface of an endless belt where it passes around a pulley. In this case, owing to the greater opposition of the air, the largest pieces should fall nearest to the pulley, with successively finer pieces as the distance from the pulley increases. If the particles are of different kinds of material and with different modes of fracturing, this mode of grading may offer means for separating the constituents by screening or other ways following the belt-grading. If the particles be of varying specific gravity the alighting position of particles of the same size will be modified to some extent by this difference, the heavier particle alighting somewhat closer to the pulley; but specific gravity differences will not affect the grading so much as differences in size or shape.

Professor C. F. Hirshfeld has experimented with this mode of grading in endeavoring to discover a means of separation for various constituents of a low-value ore which did not differ much from one another in point of specific gravity. It was found that very high belt-speed was necessary and this required that the apparatus be massive and have good foundations. Another difficulty encountered was with the differential crawl of the material on the belt under the high speed necessary. This was overcome by having two belts in contact with one another, both running in the same direction and with the same speed, the material being conveyed by the lower one and slippage being prevented by the upper. Both belts were run horizontally.

True Classification in Rising Currents of Water

Grading which is done by an uprising current of water or other liquid is called classification. In the ore-milling industry this mode of grading has some advantages over screens or other modes of grading in preparing material for certain kinds of separating machines. The technology of grading in rising currents is discussed at length in the text books on ore-dressing.[4]

Outside of ore-milling, grading by rising currents does not receive any extended use, for the work done is not sufficiently sharp for the majority of grading problems. The characteristic of any grading made by classification is the presence of grains whose size is well defined as to the upper limit, but the lower limit can scarcely be said to be defined at all. The majority of the grains are of sizes nearer to the upper limit than the lower; but in every classification there are grains of all sizes, from the largest which are rejected by the current in the grading next above any particular one in consideration, down to the very finest. When particles fall in water, beyond a very brief moment of acceleration the rate of fall is uniform, and depends upon the size of the grain—large grains falling faster than small—and on the specific gravity the greater the specific gravity the greater the rate of fall.

Formulas for rate of fall and their variation from experimental results will be found discussed at length in the authority which has been given. Theoretically, when the rising current just balances the velocity of any particular size and kind of grain, all particles of larger size should fall and smaller ones rise. In practice, the friction of the current on the sides of the enclosing hydraulic chamber, the deflections of the current caused

[3]The retardation in fall by air friction has been neglected and since the gradation of size depends on the large grains falling faster, a factor depending upon size would have to be applied to the formula to obtain the actual path.

[4]Richards' Ore Dressing will be found to be the best authority to consult, the author having been for a long period an authority on this branch of the subject.

by the falling grains and certain interstitial actions which occur between the larger grains, cause downward forces tending to carry down and deliver with a particular grading small particles which do not belong to it.

In addition to grading by rising currents there is the form of water classification which is practiced to some extent by direct settlement for varying periods of time. In the abrasive industry there are classification grades made by the settlement of the material in cones of increasing diameter. Following the grading done in this way, a barrel is filled with the overflow of the largest classification cone and the material in the barrel is allowed to settle for a definite length of time. Material which has failed to settle in this period is siphoned off into a second barrel where it is allowed to settle for a greater length of time, when the siphoning operation is again undertaken, and so on, the successive operations yielding any desired number of grades and of any desired fineness.

Methods of Grading Very Fine Materials

For grading analyses below 200-mesh, a settlement-and-siphon method is used to some extent, the results being reported as such and such percentages for such and such times.

A better mode of carrying the sizing test below the limit of screens is to take a small portion of the minus 200-mesh product and measure it under the microscope, the measuring device being a carefully ruled grid on a glass plate holding the particle to be measured.

The most generally accepted set of testing screens have the apertures diminishing in size by reducing the area of the aperture a half from screen to screen. If the glass plate be engraved with squares which diminish in the same way beginning with half the area of the 200-mesh screen, the standard width of opening of which is 0.0029 in., a count may be made of the grains which are larger than the different size squares, the various groups of oversized grains being successively removed from the sample after measuring. This method is limited by the magnification of the microscope and the skill of the investigator.

In calculating the weight of a particular grading by this method, the average linear dimension of the squares (half the sum of the side of square on which the grain is being tested and the side of the next largest square) is cubed and this factor multiplied by number of grains to obtain weight and percentage by weight. This mode of computation is, of course, only approximate and subject to much error.

The direct weighing of the particles entails great care and skill, and the difficulties of obtaining the weights and percentages by direct weighing increases as the size diminishes. Increased accuracy might result if the microscopical apparatus were mounted with a gage for taking the depth of the grain.

(*To be continued*)

Denver, Col.

Steel Plant to Have Entire Electrical Equipment.—The Inland Steel Company has placed an order with the Westinghouse Electric & Manufacturing Company, of East Pittsburgh, for the complete electrical equipment of its new plant at Indiana Harbor, Ind. The order represents an expenditure of over one million dollars and when completed the company will have what is said to be the largest electrically-driven steel plant in the world.

Aluminium in 1915.—The production of aluminium in 1915 is estimated by several authorities to be close to 80,000,000 lb. This is a record of achievement and compares with production in 1914 estimated at 45,000,000 lb.

Blast Furnace Smelting of Cyanide Precipitate

BY REGIS CHAUVENET

It is not necessary to review all of the methods which have been used or proposed for the treatment of the so-called cyanide "precipitate." These methods, to use a rather Hibernian expression include the case where there is no precipitate to treat, as for example the regaining of the gold without the use of either zinc or carbon.

Originally, the most obvious method was the first attempted. Nothing was simpler, on paper, than the solution of the zinc and all other impurities in some appropriate solvent, leaving the gold behind. It was discovered before long that there were many cases in which this was quite impracticable; and, naturally, they were so in the proportion in which the impurities were themselves insoluble or difficultly soluble in the menstruum.

Nitric acid is out of the question to begin with, on account of its expense. Take for example, copper, whose average equation of solution is:

$$3Cu + 8HNO_3 = 3Cu(NO_3)_2 + 4H_2O + 2NO.$$

We destroy 2¾ lb. of actual nitric acid for each pound of metal, approximately the same for zinc, though considerably less for lead. Indeed, the cases quite other than the one under consideration, in which nitric acid has been proposed, and abandoned on account of its cost, are numerous in the annals of hydro-metallurgy.

As for sulphuric acid, it will not dissolve lead except under "impossible" conditions. It takes up copper only by application of a mixture of air and steam. This has been used in the purification of silver, but as the question is almost always complicated by the presence of other impurities, sulphuric acid for the removal of copper at the same time with the zinc, is of a class of problems more curious than practical.

However, as is well known, sulphuric acid has been used in those cases where the total copper *plus* total lead are so low that the precipitate is substantially nothing but gold and zinc.

Fire Methods of Refining Precipitate

Other curious methods have been proposed, some of them heralded as the "long-looked-for-come-at-last." This brief discussion of wet treatments of the precipitate is intended merely to introduce the subject of fluxing, i.e., to indicate that there are cases in which some form of dry treatment, more or less approximating actual smelting operations, is imperative. There remains, to be sure, electrolytic separation, but here again conditions often prohibit.

We are reduced to three furnace methods:

(1) Direct cupellation.
(2) Reverberatory hearth.
(3) Blast-furnace.

For purposes of this discussion the first method is rejected on account of high copper.

We must here quote rather extensively from the long and highly informatory articles by J. W. Hutchinson,[1] on the Goldfield Consolidated mill, where the operations to be presently described were initiated. We condense the description of the original method of smelting, but it is necessary to indicate the difficulties of the earlier trials in order to appreciate the improvement introduced by the full smelting method.

The melting-room as originally designed, contained a double-muffle drying-furnace and four Faber du Faur tilting furnaces for treating the precipitate. The proc-

[1]Min. & Sci. Press, May-June, 1911. Reproduced in "Cyanide Practice, 1910-1913," Von Bernewitz.

ess consisted of nitre-roasting the precipitate, with subsequent melting in the tilting furnaces. Bullion from this method averaged 250 fine in gold and silver.

Later, acid-treating tanks were put in which materially reduced the amount of precipitate to be melted, and by addition of pyritic concentrate, enough copper and lead were converted to matte to raise the grade of the bullion to 425 gold and silver. (The analysis here introduced is omitted, but the bullion shows over 40 per cent of copper, 13 per cent of lead and 3½ per cent of zinc.)

No wonder that, to quote again from the article, "The process was decidedly unsatisfactory." Much work was done to ascertain whether some wet method could not be adopted. Electrolytic parting was suggested and abandoned. Another method which included matting away of the copper, gave a lead bullion high in gold and silver.

It had been about decided to try reverberatory smelting, first briquetting the precipitate with litharge and fluxing on a reverberatory hearth. Mr. Hutchinson here gives Mr. Henry Hansen of Blair, Nev., credit for the suggestion of blast-furnace treatment. It had been tried on a small scale at the Pittsburgh Silver Peak Company.

Blast-Furnace Smelting of Cupriferous Precipitate

The new departure consists in nothing less than the actual smelting of the precipitate on a lead basis, in a small furnace constructed in miniature exactly like a lead-smelting furnace. "Smelting precipitate containing 40 per cent copper on a lead basis did not sound very attractive as blast-furnace work at first," but it was soon found that it could be efficiently done.

Briquettes were made consisting of:

Dry precipitate	100 parts
Litharge	100 to 125 parts
Blanket concentrate	60 to 75 parts

This "concentrate" held 35 per cent silica and 30 per cent of sulphur. Subsequently the proportion of litharge used in the briquettes was made still higher.

The precipitates of several years had the following average percentage analysis:

	1911	1910	1909
Au	21.50	8.75	13.43
Ag	3.00	1.14	2.13
Cu	39.80	21.59	22.85
Pb	4.60	28.58	6.86
Zn	15.50	12.57	32.50

There is variation enough here to bring much "grief" to the experimenters. Nevertheless success eventually crowned their efforts.

It is evident that if the precipitate is to be treated in a blast furnace "on a lead basis," there may be two cases, viz.: matte or no matte. With high copper the only practicable scheme is the formation of a matte, and this will perhaps inevitably entrain both lead and zinc. In the absence of copper this necessity disappears. Hence came the addition of concentrate to the charge, which in the case of the high copper precipitate was left raw for the utilization of its sulphur, but when copper was practically absent it was added more for the sake of its silica (for slag formation) and its incidental value. In this case roasted concentrate was used.

In both cases the addition of iron oxide is almost a *sine qua non*, since we are to depend mainly upon the reduction of the lead for the collection of the gold and silver, and the carrying of the zinc into a slag, which would hardly possess the requisite fluidity unless high in iron.

Effect of Zinc in Slags

The composition of a slag which is to carry zinc oxide, is too well known to require much discussion. It is true that we are not trying to dictate composition, but rather method of computation of this slag, but some consideration of its essential qualities cannot be wholly omitted. Lime and zinc oxide seem to be natural enemies, so far as slagging together is concerned. It has often been given as a rule, that when lime rises into the twenties in a slag, zinc acts more and more as a stiffener, and it is said that when lime reaches 28 per cent, zinc oxide refuses to enter the slag at all. While we are not responsible for these figures, there is no doubt that zinc cannot be slagged off in smelting unless high iron is present. Iron is added in such cases to such an extent as to lessen materially the total percentage of silica.

The blast furnaces adopted at Goldfield are of the cylindrical type, 20 in. in diameter at the tuyere line, with riveted steel jackets. In blowing in the wood fire is maintained until crucible and lead-well are cherry red. Coke is added and the fire urged to white heat. Five hundred pounds of lead is fed in to fill the crucible. Blank charges of coke and slag are fed until the furnace is half full. Then comes the regular charge, consisting of:

Briquettes	100
Old slag	40
Borax	10
Cupel bottoms	51
Iron (oxidized)	5
Coke	25

So far, the old practice. The lead bullion contained under this method approximately 20 per cent gold and silver, and 1 per cent copper. The matte from these runs contained average of 20 per cent lead, 50 oz. gold and 200 oz. silver per ton. This accumulates until sufficient matte is on hand to be separately run.

TABLE I

Analyses of all the constituents of the charges, except iron oxide which is nearly pure Fe_2O_3 obtained by dead-roasting pyrite. Gold and silver contents of Consolidated and Aurora precipitates are given in ounces per ton; gold value of raw concentrate in dollars. All other figures are percentages.

	Consolidated Ppt.	Aurora Ppt.	Raw Concentrate	Roasted Concentrate	Selby Slag	Remarks
Au	3470	2578	$50	....	....	
Ag	808	2229	....	....	....	
Cu	22.0	0.2	0.5	0.6	....	
Zn	22.0	40.8	....	....	....	40.8 called; 41 in problem
Fe	....	0.5	20.0	32.2 (40 FeO)	40.0 (51.4 FeO)	
CaO	5.5	7.2	....	....	20.0	
SiO_2	....	11.6	50.0	54.6	30.0	55 in problem; 54.6 called
S	....	....	19.0	1.0	....	

Mr. Eugene G. Snedaker has kindly furnished us with analyses of the various products which enter into the problem. As to the slag produced, we are not able to pronounce upon it, as it shows a summation of less than 77 per cent, viz.:

	Per Cent
Insoluble	24.8
FeO	26.3
CaO	5.5
ZnO	12.3
Pb	6.5
Cu	1.3

"Soluble silicates and borates undetermined; gold, 1.2 oz. per ton."

This, inferentially, leaves us with the astonishing proposition that 22½ per cent of the slag consisted of bases other than those named. Here, however, we drop discussion of the practice, as it is mainly our intention to explain the computation of a rational flux addition to the briquettes.

Turning now to the analyses of precipitates, concentrates and Selby slag given in Table I, it appears that we have to consider both high and low copper, also both raw and roasted concentrate. As it is obvious that one of these cases demands a matte and the other none, we take them up as two separate problems.

Problem I. No Matte Formed in Smelting

Assuming then, that in any given charge or campaign we are to use but one of the given precipitates, we start with the Aurora.

Theory calls for the addition of about 150 lb. of litharge to 100 lb. of precipitate, to supply oxygen for the reaction:

$$Zn + PbO = ZnO + Pb.$$

In 100 lb. of precipitate (zinc = 41 per cent) the atomic weight proportion is:

$$65 : 16 = 41 : 10.10$$
$$Zn : O = Zn : O$$

And for litharge:

$$223 : 16 = 150 : 10.76$$
$$PbO : O = PbO : O$$

The margin is small, being in fact 10.76 minus 10.10, or 2/3 lb. for oxygen. Probably the addition of a little more litharge would become the practice.

Leave out of all account, in slag calculation, the gold and silver. The reduced lead, *plus* that with which you start in the crucible should take care of the precious metals. Some lead will in all probability get into the slag. With it, possibly some gold and silver. As the slag is to be re-treated this is not prohibitory.

We now use the "representative" method of slag computation already illustrated several times in this journal.[8]

We enter our calculation with 51 lb. of zinc and 7 lb. of lime, each of these from the 100 lb. of Aurora precipitate. We are figuring for a slag, and we may leave matte out of the reckoning, as we have but 1 per cent of sulphur in the roasted concentrate. This trifle of matte will be drawn off with the slag and will go into the retreatment of the latter.

What slag shall we figure for? I adopt the purely arbitrary figures SiO_2 = 30 per cent, FeO = 50 per cent and ZnO = 20 per cent. The lime is to be *included in the figure for zinc oxide.* Iron oxide (Fe_2O_3) has to be provided as flux, and it appears from the records of the company that a roasted pyrite furnished this essential constituent of the charge.

As usual assume 100 lb. as basis for your calculation, i.e., 100 lb. of precipitate. *Call your concentrate* $100x$, *and your iron oxide* $100y$.

Get expressions for total silica, FeO and ZnO (include CaO in the latter).

Remember that the Fe_2O_3 reduces in slagging to FeO, whose weight is exactly 90 per cent of the higher oxide. Expressions for all the constituents will be as follows:

	SiO_2	ZnO	FeO
From precipitate	12	58 (c)	... (a)
From concentrate	55x	..	40x (b)
From Fe_2O_3	..	..	90y
Totals	12 + 55x	58	40x + 90y

(a) Neglect the 0.5 per cent iron in the precipitate. (b) The 32.2 per cent Fe in the concentrate is equivalent to 40 per cent FeO. (c) The 41 per cent Zn is equivalent to 51 per cent ZnO; this added to the 7 per cent CaO makes 58 per cent of the two oxides.

Now by the slag conditions of the problem (SiO_2 = 30, FeO = 50 and ZnO = 20), we have $5 \times SiO_2 = 3 \times FeO$, that is:

$$60 + 275x = 120x + 270y \qquad (1)$$

Also, $2 \times SiO_2 = 3 \times ZnO$, that is:

$$24 + 110x = 174 \qquad (2)$$

These two equations which are very quickly solved, give us $x = 1.3636$ and $y = 1.005$ or $100x = 136.36$ and $100y = 100.5$. That is: for each 100 lb. of precipitate add 136.36 lb. concentrate and 100.5 lb. of iron oxide.

[8]Calculation of Furnace Charges, Regis Chauvenet, this journal, January, February, March, April and June, 1912.

Proof.—Take the quantities indicated, and calculate from the analyses the weights of each constituent added. If these come out in the proportions required, i.e., 30 : 50 : 20, the proof is perfect.

	SiO_2	FeO	ZnO
Precipitate	12	....	58
Concentrate	75	54.55	..
Iron oxide	..	90.45	..
	87	145.00	58

The sum is 290 lb. slag, and calculating the percentage of each constituent, we find that:

$$87 : 145 : 58 = 30 : 50 : 20$$

exactly as required by conditions.

The slag then, irrespective of the old slag addition to be presently mentioned, will have the composition, SiO_2 = 30 per cent, FeO = 50 per cent and ZnO + CaO = 20 per cent.

Function of Old Slag in Charge

In all smelting operations of this general description, old slag is added to each charge, to facilitate melting. In the description of the former practice it is stated that the old slag from the operation itself was added, though it became so "zincky" that it had to be rejected after a while. Instead of this addition, "Selby" slag is substituted. It is not usual, nor is it necessary, to work the analyses of this addition into the general computation. The old slag, because it does not have to go through the formation period, aids the melting of the charge. Its composition as shown (SiO_2 = 30 per cent, FeO = 50 per cent (about), and CaO = 20 per cent), is singularly near the desired final outcome. This addition of a standard slag from lead practice, is greatly to be preferred to the return of the zincky slag from the smelting of the precipitate. Incidentally, composition is bettered, because of the lowering of the percentage of zinc. It will always be a problem more or less difficult to obtain a slag which, in carrying off all of the zinc, will at the same time be fluid enough for easy handling.

It was then, not without a realization of these troublesome elements that the management adopted "Selby" slag as the regular addition to their charge.

In the computation to follow all bases other than FeO are set at 20 per cent, zinc oxide being the chief one.

Here let us say, once for all, that we wish to illustrate a method of computation, and are not dictating the composition of a slag obtained under conditions unfamiliar to us. Whether the particular proportions are the best does not cut much figure, since the method is perfectly general. Thus, if a slag proves to be too pasty because it is too zincky, lower its zinc contents and recompute the charge. In short the *method* is mathematical, not physical. We apply our knowledge of slags, of course. We remember that high lime and zinc are incompatible, and that multiplicity of bases helps fluidity, and we bring to our aid whatever local experience has indicated. This experience having given us a preferential composition, all our method does for us is to give an easy solution for compounding the charge for production of the desired result.

Problem II: Matte Formed in Smelting

We now take up the "Consolidated" precipitate, which, being high in copper, is to be smelted with raw sulphide concentrate.

We must first "take out" the matte from the raw concentrate, i.e., calculate out its iron against its sulphur. The iron is 20 per cent in the raw concentrate. Apportion it on the formula FeS to the sulphur:

$$\underset{Fe}{56} : \underset{S}{32} = \underset{Fe}{20} : \underset{S}{11.4}$$

That is, sulphur required for iron in matte is 11.4 per cent. We have 19 per cent sulphur in the concentrate, which minus the 11.4 per cent required as above leaves us 7.6 per cent which is to be adjusted to the copper of the precipitate. This sulphur may be adjusted thus; the formula of the copper sulphide in the matte is assumed as Cu_2S, which contains practically exactly four times as much copper as sulphur. That is, in 100 lb. precipitate we must add available sulphur weighing one-fourth of our copper content of 22 lb. One-fourth of 22 is 5.5. We have then simply to answer the question, "How many pounds of concentrate with 7.6 per cent available sulphur will yield 5.5 lb. of same?" That is, merely,

$$7.6 : 100 = 5.5 : 72.4.$$

That is, 72.4 lb. of the raw concentrate will supply sulphur enough both for its own iron and for the 22 per cent copper of the precipitate.

Since we have 50 per cent silica in the raw concentrate, 72.4 lb. contain 36.2 lb. silica.

In 100 lb. precipitate we have

22 zinc	=	27.4 ZnO
5.5 CaO	=	5.5 CaO
Say.....		33 lb. base

We want, say 50 per cent FeO in the slag. Now since we have 36 lb. SiO_2 and 33 lb. base, the two making 69 lb., the other half of the slag, FeO, must also be 69 lb. This weight of FeO will be yielded by 76.6 lb. of the ferric oxide, Fe_2O_3.

By pounds the slag will be:

SiO_2	36
Base	33
FeO	69
Total	138 lb.

By percentage composition this reduces to:

SiO_2	26 per cent
Base	24 per cent
FeO	50 per cent

The charge then, irrespective of coke and "Selby" slag, will be:

Precipitate	100.0 lb.
Concentrate ...	72.4 lb.
Fe_2O_3	76.6 lb.

This method of computation assumes that we must apportion the iron in the concentrate to its sulphur, and then compute the whole of the added iron oxide into slag. This is as good a way as any, but, in fact, there are half a dozen ways, more or less conventional, of adjusting the bases to sulphur and silica.

Impossible to Form Both Slag and Matte of Assigned Composition

In review it must be noted that we have here conditions whose simultaneous fulfillment is imposssible. For it will not be possible to compose a charge so that we shall have at once a slag and a matte of assigned composition. In other words we have two imcompatible conditions, which could be simultaneously satisfied only by a fairly miraculous coincidence.

Having, however, secured an approximation to the desired slag, it would be easy to get the exact requirement, provided we had perfectly pure material, i.e., material containing only silica, or only base. As to what the ideal slag for the operation would be, could be determined only by experience, and a good deal of it.

Let us exemplify by two assumptions: (1) we have the "Selby" slag, and (2) we have pure SiO_2 and pure Fe_2O_3. Now we can never get a precise solution by the addition of another slag, for the addition of one element enforces the addition of others in set ratio, i.e., only by a miracle could we get the ideal.

With separate pure material on the other hand we can always secure any desired slag. This we shall illustrate in conclusion of the article. We should add that as a mathematical principle, we may always secure any required slag provided there are but three constituents in the aggregate composition.

First. Suppose we use "Selby" slag to assist in slag formation. This, by the way, is supposing what is actually done in every charge.

As sent to us the analysis figures out 101 per cent, so we knock off 1 per cent and call the "Selby" slag:

SiO_2	30 per cent
FeO	50 per cent
Base	20 per cent
Total ...	100 per cent

Add 100 lb. of this slag to our already deduced charge, we shall have:

SiO_2	= 36 + 30 =	66 lb.
Base	= 33 + 20 =	53 lb.
FeO	= 69 + 50 =	119 lb.
Total		238 lb.

The composition by percentage is very easily figured out, giving:

SiO_2	27.7 per cent
Base	22.3 per cent
FeO	50.0 per cent
	100.0 per cent

We see that we have not made any great change in the composition. The "Selby" assists in formation but not in proportions, i.e., not materially.

It is quite otherwise when we come to additions of Fe_2O_3 and SiO_2. Take the original charge and add as shown. We are trying to secure as nearly as possible the original requirement, and to do so we add *such weights* of SiO_2 and FeO as to bring their totals to the ratio of three to five. This explains the apparently arbitrary assumption of 24 and 31 as the additions of SiO_2 and FeO. To get 31 lb. FeO we add 34.4 lb. Fe_2O_3.

Pounds in slag:

SiO_2	36 + 24 added making	60 SiO_2
Base	33 + 0 added making	33 Base
FeO	69 + 31 added making	100 FeO

Reduce the above mixture to analysis:

SiO_2	31.1 per cent
Base	17.1 per cent
FeO	51.8 per cent
	100.0 per cent

We recognize this at once as a fusible slag. It might be slightly improved by dropping silica a trifle. However, with its high iron and its bases (zinc and lime) cut down to a total of 17 we shall hardly "freeze."

Various changes may be introduced into the composition by prior calculation; the possible variants being infinite, we leave them to the student's devices. We shall give a single case. Suppose that to each 100-lb. slag (26:50:24) we are to add SiO_2 and Fe_2O_3 so as to bring it to (30:50:20). We may do so without equation, thus: The base equals 24 per cent, which by the proposed change is to become 20 per cent. Then the weight must be made 120 of which 60 (50 per cent) must be FeO; therefore, add 10 FeO (11.1 Fe_2O_3) and 10 SiO_2. Then we have:

SiO_2	=	36
FeO	=	60
Base	=	24
		120

and the required percentages are obtained, i.e., 30:50:20. Similarly any desired change can be readily made.

Denver, Col.

Recent Chemical and Metallurgical Patents

Electric Furnaces

Electric Furnace.—A pinch furnace containing several compartments is patented by Carl Hering of Philadelphia, Pa. The principle of the pinch furnace was described by Dr. Hering in this journal, Vol. IX, 1911, pages 277 and 371. The present furnace is designed primarily for melting material of low resistance, such as copper, silver, gold, or alloys. The compartments are connected with each other by channels and a circulation through the compartments is created by the pinch effect. A two-compartment furnace is shown in plan and cross-section in Fig. 1. The cross-section is taken on the line *XX* of the plan view. The furnace proper, of refractory material, is shown at *W*. The two compartments, *H*, *H*, are filled with the material to be melted. The electrodes *EE* are connected to the bottom of the compartments in contact with the molten material as shown. The channels *R'R'* meet at *P* and communicate with the common pouring spout *S*. By using more compartments, such as three or five, or more, three-phase alternating currents may be used. The advantages claimed for this type of furnace are that it permits of the use of relatively higher voltages, lessening the electrode losses, and also permits of the use of different slags in the different compartments with correspondingly different refractory linings. In refining steel, an acid slag may be used in one compartment, while a basic slag is used in another, thus avoiding the need of changing slags. By using a number of compartments, cold metal or raw material can be introduced in one compartment for melting, while another compartment may be used for refining the slag or other treatment, thus making a continuous process. The resistor channels may be made of other shapes, such as conical for the purpose of making the flow stronger in one direction than in another (1,162,773, Dec. 7, 1915).

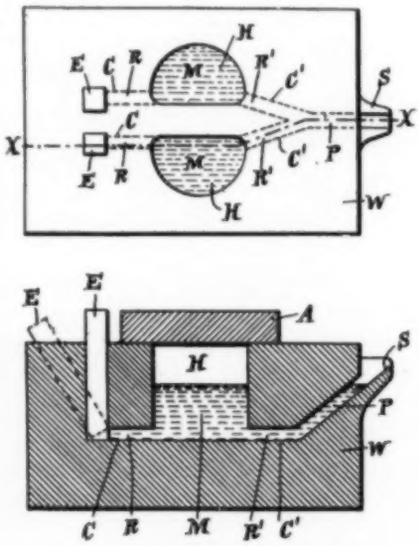


FIG. 1—PINCH FURNACE

Electric Furnace.—A patent of Alex Dow of Detroit, Mich., refers to electric furnaces using a granular resistor, such as carbon, as heating element, the object to be treated being placed above and heated by radiation from below. As the radiating surface of the resistor assumes a temperature slightly lower than the rest of the resistor, the current is caused to be deflected downward on account of the increase in resistivity of carbon with decrease of temperature. To overcome this defect in furnaces of this type, Mr. Dow places a series of bars of magnetic material (iron) below the granular resistor and at right angles to the direction of the current. These bars become magnetized and deflect the current upward toward the working zone of the furnace where the heat is needed (1,164,634, Nov. 23, 1915).

Electric Furnace for Producing Aluminium Nitrides.—A furnace for manufacturing aluminium nitride from bauxite and coal based on the original intermittent electric furnace process of Thomas L. Wilson, patented in England in 1895, is patented by George Coutagne of Lyon, France. Several modifications have been made in lower electrode and in the furnace casing. A cross-section of the furnace is shown in Fig. 2. The upper electrode *H* is a movable solid cylinder. The lower electrode is made of a large tube *A* of agglomerated coal. Between *A* and the shell of the furnace refractory material *C* is placed. Within *A* is a column of coke *B*. The nitrogen-containing gas, such as generator gas, is introduced through *D* into the annular space *E* under pressure, and is forced up through the furnace. No refractory lining is used on the shell above *C*, and all openings *K* at the top are made gas tight. In starting the furnace the upper electrode is lowered until it touches *B*. The coke is allowed to heat up for awhile, then the mixture of bauxite and coal is gradually added through openings *K*, and the flow of generator gas is started. The work of the current is localized toward the center of the furnace and the outer portions of the charge adjacent the iron casing will not conduct the current so much. This permits the use of the unlined casing above mentioned. An operation lasts several days, and when finished the whole furnace is filled. The aluminium nitride is formed in a cake at the center of the furnace when cooled down, and is surrounded by an agglomerated mass of coal and bauxite at the periphery. The nitride is subjected to a high temperature during the operation, and it is stated that the retrogression studied by Fraenkel (*Zeit. für Electrochemie*, April 15, 1913) at 1500-1600 deg. does not take place (1,158,899, Nov. 2, 1915).

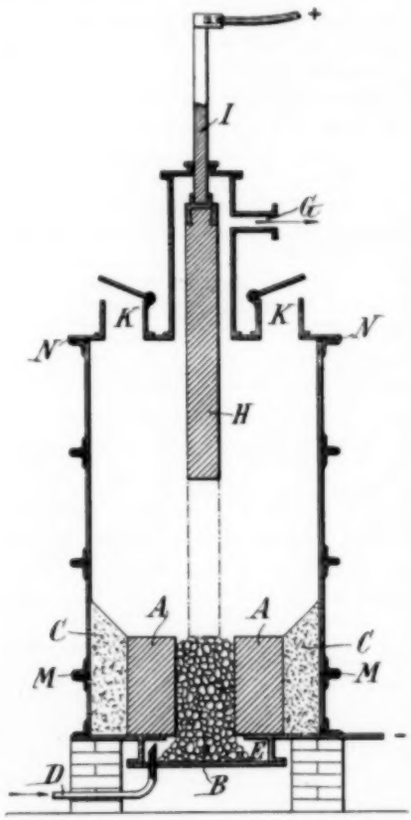


FIG. 2—ALUMINIUM NITRIDE FURNACE

Electric Furnace.—An electric furnace which utilizes the heating effect of eddy currents is patented by **Sigmund Guggenheim** of Berlin-Wilmersdorf, Germany. Three-phase currents are used, which is claimed to make the melting operation more economical by providing a greater concentration of magnetic lines in the body to be heated. The furnace consists of a receptacle containing the material to be heated, placed in the air gap between the poles of three magnets. When these magnets are wound so that their current supply is in the same sense, a large proportion of the magnetic lines of force will not pass entirely through the material to be heated, but will be diverted from one pole to the next adjacent one. If, however, the winding

of the middle magnet be made such that the current is in the opposite sense to the other two, then a much larger number of lines of magnetic flux will go through the material to be heated. This unequal displacement of the magnetic phases is the feature of the furnace. (1,157,691, Oct. 26, 1915.)

Cementing Carbon Articles and Electrodes.—In baking carbon articles a porous product is apt to result due to the escape of volatile matter while baking. This is objectionable as it raises the resistance and in the case of carbon anodes the deterioration is hastened. A process for making the articles more dense by simultaneous heating and compression is patented by JOHN W. BROWN of Lakewood, Ohio, (assigned to National Carbon Company, Cleveland, Ohio). The articles are first impregnated with a tarry binder and then placed between plates for compressing and each end connected to electric terminals. An average current density of 1000 amp. per square inch is used. After the articles have heated up the material becomes semi-plastic and flows, cementing the particles together. The pressure does not have to be applied at the start but may be omitted until the material becomes heated. In the apparatus described the pressure is applied by a hand wheel. (1,158,171, Oct. 26, 1915.)

Electrolytic Processes

Diaphragm for Alkali Chloride Electrolysis.—In order to make it possible to use high currents with a vertical diaphragm cell a patent of ADOLF CLEMM of Mannheim, Germany, proposes to use a compound diaphragm, i.e. a diaphragm made up on one side of a substance which is not attacked by chlorine and on the other side of a substance not attacked by alkali hydroxide. The construction of this diaphragm is shown in Fig. 3. A powdered material *b*, such as barium sulphate, not attacked by chlorine, hydrochloric acid, or alkali, is supported on the cathode side by a material *a*, such as asbestos, while strips *c*, of glass, ebonite, or stoneware are arranged on the anode side. The diaphragm is claimed to be very durable (1,160,847, Nov. 16, 1915).

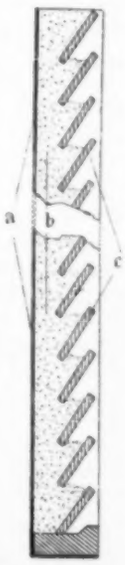


FIG. 3—COMPOUND DIAPHRAGM

Acetic Acid from Acetylene by Electrolysis.—A process for producing acetic acid from acetylene by electrolysis is patented by CHRISTIAN HANSEN and ANTON WEINDEL of Leverkusen, Germany (assigned to Synthetic Patents Company, Inc., New York City). "The anode space of an electrolyzing chamber provided with a diaphragm of clay and an anode of platinum is charged with sulphuric acid (30 per cent) and 1 to 2 per cent of mercuric oxide, calculated according to the weight of the anodic liquid, while the cathode formed of lead or copper is also immerged in sulphuric acid (30 per cent). Acetylene is then introduced into the anode space, allowing the electric current to pass through and stirring at the same time. In this process 48.5 parts of acetylene are used every hour for every 100 amp. of current. The tension of the bath at a current density of 0.25 to 0.75 amp. per square decimeter of anode surface is 3 to 4.5 volts, and the temperature of the electrolyte is kept at 30-40 deg. C. A good yield of acetic acid is obtained" (1,159,376, Nov. 9, 1915).

Electro-Osmosis

Electro-Osmotic Filter Press.—In removing water from peat, clay, kaolin and like substances, considerable pressure has been heretofore required in filter presses as the fineness of the solid particles in suspension decreased, but for colloidal matter these presses could not be used. A press in which osmosis is taken advantage of has been patented by BOTHO SCHWERIN of Frankfort-on-the-Main, Germany, (assigned to Gesellschraft für Elektro-Osmose M. B. H. of the same place). In this press the material to be treated is run into the filter press chamber as into any ordinary press. But the two walls which hold this material are made electrodes of opposite polarity. They are perforated and a filter cloth placed over them. By using electricity and pressure, combined the water may then be extracted running into the adjacent empty chambers and passing out. The form of the press is about the same as an ordinary filter press. The electrodes are made of hard lead and the pressure required will be very slight, and under certain conditions suction may be used. In removing water from peat, clay or chalk by this method it has been found that ferric hydroxide separates out at the electrode toward which the water migrates, usually the cathode, and gradually chokes the press. This may be overcome by reversing the current occasionally. (1,156,715, Oct. 12, 1915.)

Aluminium

Treating Aluminium Scrap.—A process of treating aluminium screenings, dross or slag from aluminium casting operations for the recovery of aluminium and other metals is patented by JAMES WRIGHT LAWRIE of Aurora, Ill. The scrap which may contain iron, copper, zinc or other metals is screened through a fine screen and slowly fed into a closed tank provided with stirring mechanism, outlets for gases, and means of applying external heat and pressure. The tank contains a caustic soda solution, which dissolves the aluminium and alumina. Alumina has a negative heat of solution in caustic soda, but the necessary heat is furnished by the aluminium and other substances in the material and by applying external heat. A charge consists of 3000 lb. of material and 2500 lb. of caustic soda in 5000 lb. of water constitutes the solvent. The material is fed in fast enough to furnish enough heat for solution and not too fast to cause foaming or violent boiling over. The external heat is applied at first after the heat of the reaction has been sufficiently used up, with at first only a slight pressure on the solution. Later the pressure is elevated and the solution of the alumina continued. The charge is filtered after dissolving and the residue treated for the recovery of zinc, copper and other metals. The aluminate solution is precipitated as hydrate of alumina, filtered and the solution used again. (1,156,606, Oct. 12, 1915.)

Boron

Stable Boron Nitride.—The boron nitride produced according to most processes is not chemically stable, being slowly decomposed by hot water, forming boric anhydride and ammonia, and is also liable to oxidation. A process for making a stable product is patented by George Weintraub of Lynn, Mass., (assigned to General Electric Company). He discovered that when unstable boron nitride is heated to a temperature of 2000 deg. C. or higher, a stable product results which can be heated in boiling water without any noticeable decomposition, and is less easily oxidized. The process may be carried out in an electric resistance furnace, and any unstable boron nitride may be used as a raw material. About 20 per cent of a boron compound such as borax or boric anhydride is added to prevent any oxidation of the boron nitride. The heating is continued until no more fumes are given off. The time is comparatively

short depending on the quantity used. (1,157,271, Oct. 19, 1915.)

Alloys

Hard Alloys of Lead and Alkaline Earth Metals.—In a number of patents granted to Francis C. Frary of Minneapolis, and Sterling N. Temple of St. Paul, Minn., the inventors describe alloys of lead with calcium, mangesium, strontium or barium, or all together, and with or without small quantities of copper and aluminium. It is claimed for these alloys that they excel antimonial lead in hardness and toughness, and that they may be successfully used for such purposes as type metal, or wherever an alloy is desired for molding purposes. As the metals added to the lead are used in small quantities compared with the amount of antimony used in hard lead, the new alloys are proportionately less expensive than antimony lead, particularly under conditions when antimony is at an excessively high price. (1,158,671-2-3-4-5, Nov. 2, 1915.)

Iron and Steel

Charge-Car for Sintering Machine.—In sintering fine ore in pans it has been customary heretofore to provide a removable cover with burner mechanism, but without mechanical means for quickly and easily handling the cover; also the charging and leveling of the pans has frequently been done manually. According to the details of a patented charging car designed by Messrs. Frank D. Carney and Richard V. McKay, of Steelton, Pa., mechanism is provided for raising or lowering the pan cover when the car has been run over the pan. The cover is provided with a drop bottom which carries a sufficient charge to fill the pan when dumped, and the bottom also acts as a leveling means for leveling the charge. The car carries an electric motor which actuates the mechanism as well as tanks for oil and compressed and means for supplying the air tank with air at suitable pressure. These tanks supply fuel and air to the burner, which is on a level with the dumping bottom. A feature of the device is the delivery to the pan of a charge of uniform compactness, resulting in a reduction of the amount of fine, unsintered material remaining after the operation. (1,158,982, Nov. 2, 1915.)

Briquetting Process.—A process for making briquets from iron ore, flue dust, pyrites cinders, etc., for smelting is patented by Mr. Dandridge H. Bibb of New York City (assigned to the Continental Process Corporation of Briarcliff Village, N. Y.). In the process the binder used is pyroligneous tar obtained from wood distillation. In briquetting flue dust it has been found that from 6 to 8 per cent by weight of pyroligneous tar will give a good briquet. The tar is first heated to the viscosity of a heavy mineral oil and then mixed with the granular material in any suitable apparatus. The mixture is then pressed into briquets and heated for ten to fifteen minutes to 250 to 300 deg. C. It is claimed that no disagreeable fumes will result. Another patent of the same inventor proposes to use as a binder the waste liquor obtained in the sulphite process of paper making. This liquor is evaporated to 30 or 32 deg. Baumé and mixed as above and the briquets pressed and heated for about twenty minutes to 300 deg. C. This treatment is claimed to give a water-proof, strong and compact briquet and to overcome all the previous difficulties experienced in using waste sulphite liquor as a binder. Another patent proposes to use as binder the waste sulphite liquor from the manufacture of chemical wood pulp. This binder is used the same as those mentioned above. Still another patent proposes to evaporate the waste sulphite liquor from paper making until a hard soluble pitch-like residue is obtained. This is pulverized, a solution made of it and mixed with the material to be briquetted. The treatment from then on is the same as in the preceding patents. (In the order mentioned the patents are 1,158,363-4-5-6, Oct. 26, 1915.)

Gold and Silver

Slime Filter, and Method of Forming and Washing Solid Cakes.—In the ordinary process of filtering ore slime for the recovery of valuable solution, it is customary to use vacuum filter leaves on which a cake will be formed. The leaves are spaced apart and the cake formed on any leaf is not formed thick enough to come in contact with the cake on an adjacent leaf. These leaves may be inclosed in a drum into which the material to be filtered may be forced, and the process of filtration caused to proceed by pressure. In patents granted to David J. Kelly of Salt Lake City, Utah, the inventor describes a method of forming "solid cakes," that is, cakes which are continuous between adjacent filter leaves. He also discloses his method for effectively washing such cakes. His filtering apparatus consists of leaves within a drum, with suitable connections through the container for the withdrawal of the filtrate. These connections are combined in a manifold pipe with necessary valves for controlling the flow of solution. In operation, the ore slime is forced into the drum and the separation of liquid and solid takes place under pressure, the liquid issuing from the drum and the solid forming a cake on the filter leaves. Filtration is continued until a solid cake is formed between filter leaves. In order to wash such a cake, valves are so arranged that water can be forced into alternate leaves, whereupon it passes out of these leaves through the cakes on either side and into the intermediate leaves from which it again issues from the drum. When the cakes have been sufficiently washed they are discharged by opening one end of the drum and running the leaves out on a track. The leaves may be flexibly mounted, and by moving them laterally the cake will be dislodged. (1,158,055, Oct. 26, 1915.)

Zinc-Dust Feeder.—Apparatus for emulsifying and feeding zinc-dust in measured quantities in accordance with the gold and silver content of cyanide solutions, is shown in vertical section of Fig. 4, being patented by Herbert C. Colburn of Victor, Colo. It consists of a supply bin 3 for zinc-dust, under which is mounted a screw conveyor 7. The latter is intermittently rotated by a friction ratchet 8 and oscillating member 9 which, by means of an adjustable pitman 10, is connected with gearing driven from a line shaft not shown. The pebble mill 20 is driven from the same line shaft. The dust discharged by the action of the screw falls into a bowl 16, from which it is borne to the pebble mill by a stream of barren solution issuing from pipe 17. The quantity of zinc-dust fed to the mill during any fixed period is determined by the capacity of the scoop 21, and the rate of velocity of mill rotation, so that there will be a continuous uniform discharge of emulsion from the hollow trunnion of the mill after the ma-

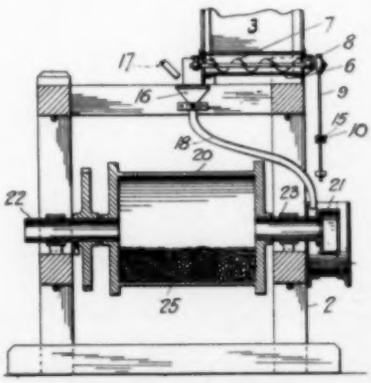


FIG. 4—ZINC-DUST FEEDER

terial has been subjected to the grinding and emulsifying action of the pebbles, of which the mill is about one-third full. (1,149,426, Aug. 10, 1915.)

Copper

Melting and Refining Copper.—An improvement on the practice of melting and refining copper in a furnace having silicious walls and bottom is contained in the specifications of patent granted to LAWRENCE ADDICKS of Perth Amboy, and CLARENCE L. BROWER of Chrome, N. J. According to the improved practice the copper is treated in a furnace having walls of chrome brick and hearth of magnesite brick. A furnace thus constructed with basic lining is not subject to the erosion and consequent weakening of the structure as with acid lining. Furthermore, the contamination of the molten copper with slag is practically avoided. The practice is of value in the treatment of the three classes of materials ordinarily dealt with in copper refining, viz., foul material, blister copper and cathode copper. The basic furnace permits the treatment of foul material by itself, without the admixture of large quantities of relatively pure material as in acid-furnace treatment. In refining blister copper the basic treatment diminishes the production of slag. In melting pure cathodes, slag is practically suppressed instead of being formed to the extent of about 3 per cent as in acid practice. In any refining of copper the molten charge after skimming should be covered with a layer of carbonaceous material to avoid further oxidation, and precautions should be taken against the introduction of slag from fuel ash. (1,148,814, Aug. 3, 1915.)

Continuous Leaching Apparatus.—The interest being taken in the leaching of copper ore is reflected in apparatus patented by M. C. GODBE of Salt Lake City, Utah, for the continuous treatment of ore by the principle of counter-current flow of solution. The device consists of an annular rotating table, the deck of which is divided by radial partitions into segmental filter units. Beneath the table is a stationary annular launder divided into compartments corresponding in number with those of the deck, and provision is made for the filtrate to flow into this launder. Above the table deck are stationary solution boxes or launders occupying positions above the radial partitions which divide the deck into filter units. Means are provided for feeding the ore onto the table and for removing it after it has been leached. Injectors or air-lifts are also provided for transferring the filtrate from any compartment of the launder beneath the table to the next preceding solution box above the table, in relation to the direction of rotation. In operation the ore is delivered onto the revolving deck in a uniform layer, and as the table revolves it brings the ore on each unit successively under the boxes from which leaching solution is delivered over the charge. As the ore progresses from the point of feed to that of discharge it is acted upon by solutions of gradually increasing strength, and when it reaches the last step in the treatment it receives the strong or barren solution. Water is used for displacing the barren solution just before the ore is discharged from the table. Since the injectors transfer the solution in counter-current to the "flow" of ore, the liquid becomes enriched in metal content as it progresses toward the point of initial treatment, whence it is drawn off for recovery of metallic copper. (1,150,263, Aug. 17, 1915.)

Nitric Acid Treatment of Copper Ores.—In the issue of this journal for November, 1911, page 571, there was a description of the so-called Rankin process of ore treatment. Those who are interested in following the matter still further will find the claims for nitric acid treatment disclosed in a patent granted to HARRY D. RANKIN of Crafton, Pa. The process is about to be operated by the Nevada-Douglas Consolidated Copper Co., at Ludwig, Nev. (1,150,787, Aug. 17, 1915.)

Electrolysis with Revolving Electrodes.—Electrolytic apparatus for the treatment of copper solutions at greater efficiency has been patented by WILLIAM E. GREENAWALT of Denver, Colo. The essential feature of the device lies in means for rotating the anodes in order to bring about a rapid change of solution in contact with the electrodes. A diaphragm separates the cell into anode and cathode compartments. The invention is applicable to the treatment or cyanide solutions of gold and silver as well as to those of copper salts. (1,144,538, June 29, 1915.)

Zinc

Device for Cleaning Retorts.— An invention which may be described as a "vacuum cleaner" for the retorts of a zinc furnace is described in a patent issued to NICHOLAS L. HEINZ of La Salle, Ill. The object of the invention is to reduce dust losses in cleaning retorts and conveying the dust to a place of deposit. A vacuum pipe is extended along the front of a furnace, with a plurality of fittings to which a flexible hose can be connected. The flexible hose terminates in a pipe which is inserted into the retorts, and through which the dust is drawn to a suitable container. (1,160,077, Nov. 9, 1915.)

Roasting Zinc Flotation Concentrates.—The difficulties encountered in roasting the fine concentrates produced in the flotation process have resulted in devising various means of roasting such material without entailing excessive dust losses. One of these is disclosed in a patent granted to LOUIS C. DREFAHL of Cleveland, Ohio, the patent being assigned to the Grasselli Chemical Co. of Cleveland. The essential features of the invention consist in mixing the fine concentrates with moisture to make a plastic mass, and possibly with a binder such as ferrous sulphate. This mixture is then conditioned in a pug-mill and then expressed through a perforated plate, issuing in a number of streams of pulp, each about the diameter of a lead pencil. These fall onto an endless moving belt and break up into short fragments, and are carried by the belt through a furnace chamber where they are dried by hot gases. The material thus treated is said to withstand handling by shoveling or otherwise without much further disntegration, and can be roasted without undue dust loss. (1,153,203, Sept. 14, 1915.)

Smelting Zinc Ores.—With the object of increasing the yeld of spelter in the smelting of zinc ores, and simultaneously decreasing the production of blue powder, SAMUEL PEACOCK of Philadelphia, Pa., has patented a process of smelting zinc ores by substituting silicon carbide for carbonaceous fuel in the smelting mixture. The reaction of the mixture would be represented in the following equation:

$$SiC + 3ZnO = 3Zn + SiO_2 + CO.$$

With three equivalents of zinc being given off, the concentration of zinc vapor in the furnace gas would be three times as great as with the present method of smelting, and therefore a much larger proportion of the zinc in the ore would be recovered as molten metal without reducing the concentration of vapor to the point where blue powder would be produced. (1,154,802, Sept. 28, 1915.)

Recovery of Zinc from Zincky Slags.—Attempts have been made at various times to recover in an economical way the zinc contained in slags produced in Western smelters. One of these is outlined in a patent

granted to Sewall Truax of Canon City, Colo. The process was used for a short time at Canon City on zincky slag from the dump of the United States Smelting Co. The principle of the method is to melt the slag in a reverberatory furnace, the hearth of which is composed of reducing material, such as a mixture of coke dust and clay. The coke reduces the zinc compounds to elemental zinc which is then volatilized. Later the zinc is converted into oxide in the atmosphere of the furnace, and this is collected in a bag house. The consumption of carbon is about 20 per cent of the zinc driven off; or, in the case of a slag containing 10 per cent zinc, the consumption of coke is about 2 per cent of the weight of slag treated. The inventor states that experiments indicate that the zinc above 0.5 per cent to 0.6 per cent of the weight of the slag is readily removed. Of course the hearth of the furnace has to be renewed from time to time. (1,155,628, Oct. 5, 1915.)

Hydrometallurgy of Zinc.—In the accompanying Fig. 5 we illustrate in diagrammatic form the steps in a process for the extraction of zinc from its ores and the electrodeposition of zinc thus extracted. The

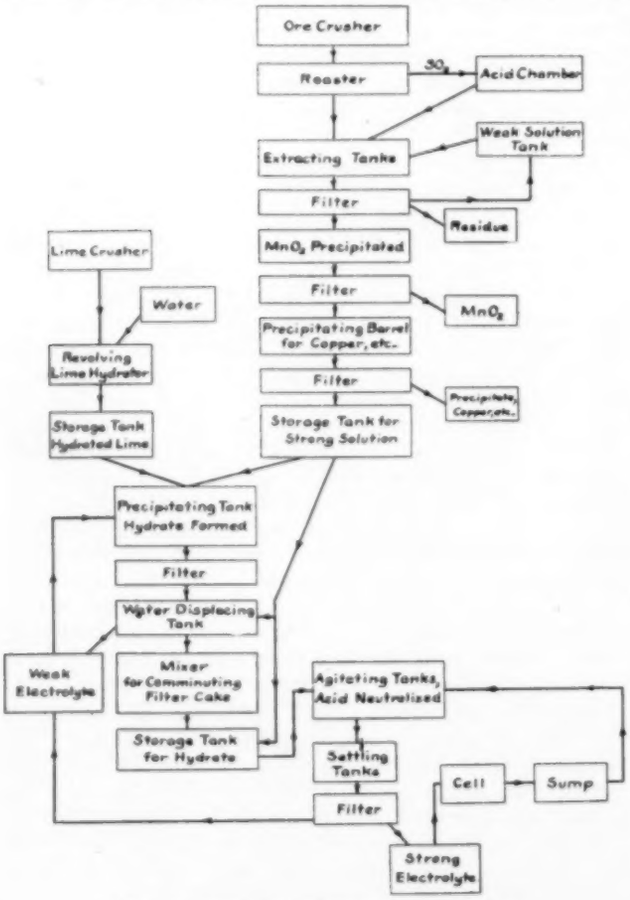


FIG. 5—HYDROMETALLURGY OF ZINC

process is one patented by Otto Best of San Francisco, Cal. The features of the process lie in the purification of the zinc sulphate solution before electrolysis. The prepared ore is leached with sulphuric acid. Iron, alumina and silicic acid are removed by treatment with lime, followed by filtration. The next step is the removal of manganese by adding to the zinc sulphate solution an alkaline permanganate, such as calcium permanganate, in the presence of lime or calcium carbonate. This precipitates manganese as the dioxide which is filtered off. Copper is then removed by treatment of the solution with an excess of granulated zinc and removed by filtration. The filtrate is now practically pure zinc sulphate solution, and as much of it as is needed is used to fill and keep filled the electrolytic vat. Zinc hydrate is now precipitated from solution by means of hydrated lime. The precipitate is filtered and the water therein displaced with strong electrolyte, after which the precipitate is held in suspension and fed to the acid neutralizing tanks as required. From the cell the acid electrolyte passes to a sump where suspended matter is removed, after which the electrolyte passes to the acid neutralizing tanks where the acid is neutralized with the zinc hydroxide precipitate. Neutralization and electrodeposition are effected cyclically by means of the freshly precipitated zinc compound, without, however, diluting the electrolyte, the strength and purity of which are constantly maintained. (1,154,602, Sept. 28, 1915.)

Extraction and Electrolysis of Zinc from Smelter Fume.—In a patent granted to Otto Best of San Francisco, Cal., the inventor describes his method of treating smelter fume for the recovery of contained zinc. The experiments were performed on a smelter fume containing from 30 per cent to 35 per cent zinc in the form of oxide and sulphate. The fume is first roasted at a temperature below that of sulphatic roasting. By this treatment the material is rendered filterable; the organic matter is destroyed; the material is freed from arsenic which can be recovered; iron is oxidized and rendered practically insoluble in weak acids, and small amounts of sulphides are oxidized to oxides and sulphates. The roasted material is then leached with weak sulphuric acid, whereupon zinc is dissolved and a solution obtained which is much purer than one produced by leaching the unroasted fume. All impurities can be removed by zinc oxide and a little sodium sulphide, used either successively or in one process, according to the impurities present. From the highly purified zinc solution, zinc hydroxide is now precipitated by means of a caustic alkali, and soluble impurities removed by washing and filtration. Electrolysis of the zinc compound can then be accomplished by a manner illustrated in Fig. 6 in which C represents a cell filled with zinc sulphate. This runs over into a storage tank S and contains zinc sulphate and some sulphuric acid. A pump P lifts the solution to two filters A_1, and A_2, having false bottoms and filled with the precipitated zinc hydroxide mixture. The solution is run through these filters at such a rate as to produce the desired acidity in the cell C. The practically neutral solution from these filters may pass through another filter A_3, which also contains zinc hydroxide precipitate, to get rid of any possible traces of free acid, and then delivered to the cell C in a pure neutral state, when a small amount of sulphuric acid, best suited for the electrolysis, is added. (1,154,601, Sept. 28, 1915.)

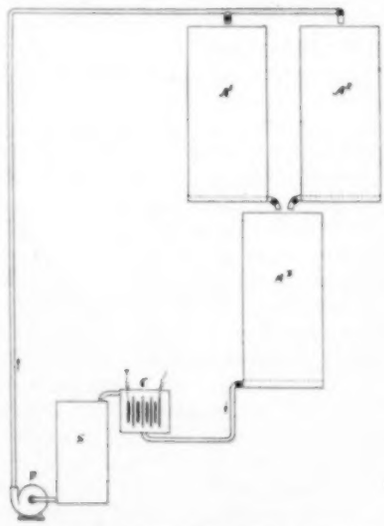


FIG. 6—ELECTROLYSIS OF ZINC SULPHATE

Synopsis of Recent Chemical and Metallurgical Literature

Zinc

Lungwitz Zinc-Smelting Process.—At a recent meeting of the New York section of the Mining and Metallurgical Society of America, Mr. WOOLSEY MCA. JOHNSON gave his experience with an unsuccessful attempt to operate the Lungwitz process of smelting zinc ores under such pressure that the zinc vapor was kept liquified. This process was patented by Dr. Emil Lungwitz about twenty years ago, and some spelter was produced experimentally by Dr. Lungwitz and Dr. Robert C. Schupphaus in Berlin. On the basis of the experimental work, Mr. John E. Dwight fathered a scheme to try the process on a larger scale for the treatment of a complex zinc ore, obtaining copper matte, lead bullion and spelter. The ore tested was from New Hampshire and contained 20 per cent zinc, 7 per cent lead and 1 per cent copper in a mica gangue. The pressure blast furnace was erected at Warren, N. H. The talent engaged comprised Fred C. Gordon, E. A. Uehling, D. V. Keedy, Carl F. Dietz and Mr. Johnson.

"The apparatus used was a round, pressure blast furnace, 3 ft. inside at the tuyeres, 5 ft. 6¾ in. at the bosh, with a height from tuyere line to charging floor of 25 ft. 3 in. The furnace was supported by four steel battered columns of latticed channel bars. The crucible was thus exposed to view. Five 3-in. water-cooled tuyeres were used, in each of which a bronze plug with three ⅞-in. holes diffused the blast into the smelting zone. The shaft was made of ⅞-in. plate, triple rivetted. The charging was done by a massive double bell and hopper of cast steel. The pressure in the furnace was regulated by two "bleeders" on top, like safety valves. The crucible and bosh were lined with chrome brick, and the shaft with good fire brick. It was possible to spray with cooling water any section of the furnace, which was blown by a two-stage Ingersoll-Sargeant 7-drill compressor giving 1000 ft. of free air per minute. In general, it resembled a conventional iron blast furnace, modified to meet the imposed conditions of operating at 60 lb. pressure. The engineering effect was as good as could be desired, when the unusual and difficult nature of the feat was considered.

"As a result of discussion it was seen that the pressure and temperature limits of the smelting zone would be at least narrow. It was accordingly determined to make a pressure-temperature curve of the system "liquid-vapor zinc" and fluidity tests on the running points of various slags.

"For the first-named purpose, after several trials a 'bomb' was made of a piece of 5-in. shafting 30 in. long, drilled with a 3.5-in. hole. In one end, the lower, an outside hole was drilled to receive a pyrometer couple in close proximity to 500 grams of spelter. The bomb was placed inclined in a small kerosene-fired reverberatory so that the upper end projected through a luted hole in the furnace. There was a pipe connection from this to a small receiver, which had a pressure gauge and a relief-valve operated by hand. In this way the line pressure of 120 lb. could be controlled to any desired pressure from zero to 120 lb. In the bomb, 3 in. from the molten zinc was a 0.01-in. hole and 3 in. from this a second 0.01-in. hole. The bomb was filled with coke (88 per cent fixed carbon) sized between 4-mesh and 10-mesh. Thus, when the bomb was under heat and pressure two small flames of carbon monoxide burned from these two tiny apertures. When the pressure was slowly reduced, the carbon monoxide flames suddenly changed to brilliant zinc flames when the boiling pressure of zinc at that temperature was reached.

"After some failures, we found it necessary, after each determination of the boiling point of the zinc, to increase the pressure so as to clean the coke from all zinc either as liquid or vapor. In this manner all false flames caused by "fuming" were eliminated. It was also found necessary to shut off the oil flame while taking the readings, as the indicating flames were otherwise not easily visible. When the details of operation were understood, accurate and comformable results were attained. The curve above the boiling point of zinc at atmospheric pressure, *i.e.* 920 deg. C., is nearly a straight line, and for each pound increase in pressure the boiling point is raised 6.1 deg. C.; at 25 lb. it is 1080 deg. C.; at 75 lb., 1350 deg. C.

"For determining the fluidity of slags we used the Johnson slag-tester, described in *Trans.* A. I. M. E., Vol. XLIV, page 139. This gives accurately the temperature at which the slag in question drips through a small hole, a point analogous to that at which the slag in the smelting zone drips over the coke. We made and tested about 70 slags, and finally determined on a sesquisilicate containing 8 per cent CaF_2, 15 per cent, FeO, 5 per cent, Na_2O, remainder lime and silica. This slag is fluid at a few degrees above 1000 deg. C., whereas lead blast furnace slag is fluid at about 1100 deg. C. It was impossible for use to use a high percentage of ferrous oxide, for fear of formation of "iron sows," under the more intense reduction needed in the Lungwitz process.

"With knowledge of these factors, we could operate the furnace with some degree of certainty. There was raised, however, the question of "the law of partial pressures." For liquifying any vapor, the full pressure of the vapor must exist next to the surface of the liquid. Now, in the furnace operations at Warren, for each cubic foot of zinc vapor there were some 9 cu. ft. of indifferent gases, carbon monoxide and nitrogen, sweeping through the smelting zone. Accordingly, should any zinc be liquified it would be evaporated by this sweep unless the pressure were ten $(9 + 1)$ times as large as had been considered and calculated. The condition was analogous to a steam condenser with too much air in the system. This point was brought out in discussion, but it was decided to start at any rate. It was found later that it militated strongly against the success of the Lungwitz process.

"The furnace was started, after three weeks' overhauling had made it tight to 80 lb. air pressure, by inserting a torch through the tuyeres and lighting cord wood on which was a charge of coke. Above that was a burden of coke and slag-making materials. Tests of the charging, pricking the tuyeres, and tapping slag were made. The pricking of the tuyeres made an infernal racket, but could be done successfully. Finally the slag level came up to the height of the tuyeres and a test of the slag-tapping arrangement was made. This was designed with a cast-steel hood in the form of a large ell over the slag notch, to which was bolted a cast-iron cylinder leading to a brick run-way for the slag. In the cast-steel were two holes, through the lower one of which a modified Scott "mud botting-gun" could be inserted. Through the upper hole, the tapping bar could be inserted. While the entire force retired to a considerable distance on the side hill, the writer and Mr. Allen, now superintendent of the Columbia works of the National Carbon Company, with internally repressed trepidation but with all possible show of sang-froid, attacked the position of the enemy. The bar was driven in with ease. On pulling it out, the slag was voided instantaneously in a large aerated mass, and ran down the run-way like a thing possessed; the mud-gun was next pushed by the pneumatic cylinder

against the slag-hole and the bott sent home. Contrary to my expectation, the tapping of slag and botting the furnace under 60 lb. pressure was successful in its first trial. Later, we repeated it at the working pressure of the furnace, and so long as the crucible of the furnace was hot and its contents liquid there was little trouble. The charging of the furnace gave but little trouble as the heavy bell and hopper were actuated by powerful air cylinders, and pieces of charge on the bearing surfaces could be shattered.

"The furnace ran along for three weeks but finally froze. I think that steam from the wet charge condensed in the ganister filling between the shell and the lining and finally made its way to the crucible. At all events, a lot of water got into the crucible, while there was no leak from the cooling systems. The furnace made no spelter at all, but the lead produced carried a few tenths of zinc. As the reduction was intense, the slag analyzed only a trace of lead. Some zinc, as was natural, was carried up the shaft and condensed. In a longer campaign, I believe that bad scaffolding would have occurred at intervals. The work at Warren was abandoned after this test. Mr. Gordon later built a furnace near Philadelphia having a shaft 60 ft. high and 4 ft. in diameter, with a condenser near the bosh. He finally made a few thousand pounds of spelter. With his death, the work was given up.

"We can thus chronicle the last and most serious attempt to make spelter in the blast furnace. The work was done with elaborateness, without regard to expense, and with all possible engineering care. It can be concluded that inherent metallurgical difficulties prevented the success of this scheme and will prevent that of any other similar scheme. In short, while a brilliant attempt had attained some success in working out apparently insuperable practical details to a certain degree, the law of partial pressures attacked the very heart of the process and made it faulty in theory."

Gold and Silver

Metallurgy of the Sons of Gwalia Ore.—In our issue for Dec. 1, 1915, we gave a synopsis of certain features of the plant of the Sons of Gwalia, Australia. This is now supplemented by some metallurgical details from an article by Thomas B. Stevens in the September *Journal* of the Chamber of Mines of Western Australia.

The ore is a sulphide of iron in a gangue of highly sheared greenstone schist containing quartz and calcite. Following is a typical analysis:

	Per Cent
Silica	68.40
Alumina	9.71
Ferric oxide	1.85
Calcium oxide	3.61
Calcium carbonate	11.94
Magnesium oxide	2.15
Pyrite	3.15
	99.91

The value of the gold content is slightly over 30s. ($7.50) per ton; the gold is alloyed with one-twelfth its weight of silver. Free gold occurs in the quartz, but the pyrite is the richest part of the ore. The following grading analyses on a sample crushed to pass 30-mesh show the distribution of the value in the original ore and after it has been amalgamated.

Grade	Per Cent	Assay Value in Shillings Before Amalgamation	Assay Value in Shillings After Amalgamation	Extraction on Grade. Per Cent
+ 60	17.9	39.8	38.9	2.3
+ 150	20.2	46.0	30.9	30.5
— 150	14.4	112.0	26.0	76.8
Colloidal slime	47.5	12.0	8.0	33.3
Bulk (calculated)	100.0	38.2	20.3	46.8

Extraction by amalgamation is seen to be highest on the minus 150-mesh grade, even though this contains the greatest percentage of mineral; but equally good extraction can be had on the plus 150-mesh grade if it is ground fine enough. For successful cyanide treatment, the economical limit of grinding is minus 150-mesh.

A feature of the rock-breaking plant is the use of a gyratory to crush in one operation a large tonnage suitable for stamp feed. The gyratory is well suited to the crushing of this ore, the greater part of which comes in flat slabs which would pass a jaw breaker without being crushed.

Stamps weigh 1225 lb. when new, having been increased in weight from 1000 lb. The old camshafts, 5½ in. in diameter, are found too light for the additional weight and show a short life. Cast-iron dies are used, as it has been found that a more constant tonnage can be crushed than with steel dies, on account of a more even wearing surface being maintained under the shoes. When crushing through screen of 0.097 sq. in. aperture, with a 4.75:1 ratio of water to ore, a duty of 10 tons per stamp per day can be maintained.

Grinding pans and tube mills are used for fine grinding. The former were part of the original equipment and are still used for amalgamating a part of the gold. Recovery by this method amounts to 20 per cent of the total, and the removal of so much gold at this point relieves the cyanide department of possible losses from high-grade solutions and soluble gold loss at the filters.

The following table compares the work of the different grinding machines:

	Total Cost Running One Unit One Day	Tons —150 Grade Produced Each Day per Machine	Percentage of the Total Tonnage of —150 Grade Produced	Cost of Producing One Ton of —150 Grade, in Pence	Tons —150 Grade Produced per Hp. Day
Five stamps	2.65	18.0	38.0	35.4	1.20
Pan	1.36	7.4	15.0	44.0	0.59
Tube-mill	5.17	54.0	33.0	23.0	1.20

Some interesting figures have been compiled to show what proportion of the gold is dissolved at various points in the process. In each case estimates were made by determining the difference between the assay value of solutions entering and leaving the machines and then calculating to tons of dry slime.

Dissolution of Gold

	Shillings per Ton	Per Cent of Total Gold Dissolved
In battery boxes, less than	0.5	1.5
In pans	6.5	19.4
In tube-mills	2.7	8.0
In launders, classifiers and thickeners (estimated by difference)	5.0	14.9
In agitators	9.6	28.7
Total dissolved	24.3	72.5
Amalgamated in pans	6.7	20.0
Left in residue	2.5	7.5
Value of original	33.5	100.0

A high filter duty is obtained due to the porous nature of the slime. Using a vacuum of 27 in. and a pulp of 40 per cent solids, a cake 3 in. thick and containing 28 per cent moisture and 20.5 lb. dry slime per square foot can be obtained in 20 min. Each square foot of filter cloth filters nearly 20 tons of slime before it is discarded.

Loss of soluble gold in discarded slime is 3d. ($0.06) per ton, and cyanide loss is under 0.1 lb. KCN.

In order to get good precipitation it is necessary to maintain the zinc-lead couple in the boxes. This is done by allowing a drip of lead acetate to run continuously, delivering about 0.3 oz. per ton of solution. This has been more efficient than coating the zinc with lead or introducing lead salts at the tube-mill or agitator.

The cost of treatment for the past six months, on an average tonnage of 13,534 tons has been:

Rock breaking and transport	$0.0888
Stamp milling	.2678
Pan-grinding and amalgamation	.1456
Tube-milling	.1902
Agitation and filtration (including all water used for treatment purposes)	.5490
Precipitation and smelting	.1504
Cost per ton	$1.3918

Cyanide Consumption on the Rand.—In an extensive article by H. A. WHITE in the September, 1915, issue of the *Journal* of the Chem. Met. & Min. Soc. of South Africa, the author gives the results of his investigation into the causes of cyanide loss in Rand mills. The average consumption of cyanide on the Rand for 1914 was 0.4 lb. per ton of ore treated, and the annual requirement was about 5000 tons.

An estimation, as NaCN, of the amount of total cyanide, ferrocyanide and sulphocyanide in sand residue as discharged at the Simmer Deep showed a loss of 0.0344 lb. NaCN per ton of pulp in sand treated. A similar estimation on settled slime after treatment and before discharging showed a loss of 0.1219 lb. NaCN per ton of pulp in slime treated. Similar experiments with sand and slime at the Rose Deep showed NaCN losses per ton amounting to 0.0583 lb. and 0.0653 lb. respectively.

To determine the loss due to the escape of HCN from exposed solutions, experiments were conducted with sump solutions in glass jars of 300 c.c. capacity and a surface exposure of 84 sq. ft. per ton of solution, compared with 5 sq. ft. in a sump 6 ft. deep. The results showed that loose or incomplete covering is useless in preventing loss of cyanide; that with weak solutions little loss as free cyanide occurred while protective alkali was present; that with strongest solutions the loss, both as free and total cyanide, became serious when protective alkali fell below 0.01 per cent NaOH, and, finally, that zinc in solution greatly decreased the loss of HCN due to hydrolysis.

A further experiment was made with strong and weak stock solutions and new solutions without protective alkali, by placing duplicate quantities of each in open vessels and stoppered bottles, and titrating the free cyanide in each sample at intervals from six to ninety-five hours. The exposed solutions suffered notable losses of cyanide while the stoppered solutions remained at almost original strength.

Exposure tests with working solutions under varying conditions of temperature, time, alkalinity and cyanide strength, showed that the loss is much greater in pure synthetic solutions, even with added alkali, than with ordinary stock solutions; that higher temperature increased the loss; that high protective alkalinity reduced the loss by preventing hydrolysis.

Prevention of Hydrolysis in Cyanide Solutions.—This subject is exhaustively treated by HUGH M. LESLIE in the *Journal* of the Chem. Met. & Min. Soc. of South Africa for September, 1915. The author regards hydrolysis as responsible for great losses of cyanide in the treatment of gold ores, and gives the results of his investigations on the subject. He contends that the evolution of hydrocyanic acid due to hydrolysis is accountable for the large excess of cyanide which has to be used over and above that required for efficient extraction. As a remedy he proposes a "closed" system of cyanidation, in which the vats and tanks are covered. His ideas on this subject have been patented, the United States patent being reviewed in our issue for Dec. 15, 1915, page 972.

In a simple cyanide solution kept at temperatures varying between 42 deg. and 49 deg. Fahr., the following losses were noted due to hydrolysis:

Interval, Hours	KCN Test, Per Cent	KCN Loss, Per Cent
4	0.368	7.56
24	0.232	37.00
22½	0.116	50.00
23½	0.028	75.80

With higher temperatures the loss is markedly increased, and in agitation with model Brown agitators there is a steady loss as agitation proceeds.

Exposure tests with simple cyanide solutions of different strengths show that the weaker the solution the greater the percentage decomposition. They also show that the alkali formed as a product of hydrolysis has little or no protective action on the remaining cyanide, and that hydrolysis proceeds until all the cyanide is consumed.

In contrast to these experiments, the author conducted tests in closed vessels, showing that the loss of cyanide is very small as compared with that in open vessels. He concludes that a very great loss must occur from hydrolysis in actual practice where the vessels are open, and that great protection can be afforded by a "closed" system.

In order to confirm his theories in actual practice he conducted tests at operating plants. At one mill he made tests on the slime department only, showing that there was a loss of cyanide due to evaporation amounting to 0.0013 per cent KCN per twenty-four hours, aggregating 32,572 lb. of cyanide (100 per cent strength) per annum. This figure did not include the losses in other departments, but serves to show the enormous loss which may be attributed to hydrolysis.

Parallel leaching tests were then made on a small scale with open and closed systems, in order to get comparative data on cyanide losses. The following average figures for cyanide consumption were obtained:

	KCN, Per Cent	Per Ton, Lb.
Open system	100	0.6375
Closed system	100	0.6283
Open system	130	0.4900
Closed system	130	0.3290

This shows a difference per ton of 0.2092 lb. 100 per cent KCN, or 0.1610 lb. 130 per cent KCN, or 33 per cent in each case.

The actual consumption in the tests was greater than is obtained in practice at the mill where the tests were made, figures for the latter being about 0.390 lb. 100 per cent KCN, or 0.300 lb. 130 per cent KCN. If these figures are used as representing the actual conditions, and the "closed" system consumption reduced by the difference between these actual figures and the test figures for open system, the comparative figures will be:

	KCN, Per Cent	Per Ton, Lb.
Open system	100	0.3900
Closed system	100	0.1806
Open system	130	0.3000
Closed system	130	0.1390

These figures show a saving due to protection afforded by a closed system amounting to 54 per cent in each case, or, based on a consumption of 0.3 lb. per ton with cyanide at 32 cents per pound, it would amount to a saving of about 5.2 cents per pound.

Similar tests on slime in agitators by the closed and open systems showed a saving of cyanide by the closed system. Other tests are given, all of which lead the author to conclude that there is possibility of making a marked saving of cyanide by using a closed system of treatment.

Bromine.—It is announced that the bromine wells near Pomeroy, Ohio, and Mason City, W. Va., have again been put in operation after an idle period of a number of years. The present production is expected to be 5 tons to 6 tons monthly.

A New Electrolytic Cell for Making Pure Oxygen and Hydrogen

The demand for oxygen and hydrogen for various industrial uses has grown very rapidly in the last five years. Certain lines of manufacture have been built up based on the oxygen process of welding, such as welded tanks, steel barrels, automobile parts, tubes, etc., while for repairing broken machinery, for reclaiming castings, for metal cutting of every nature, oxygen and hydrogen or oxygen and acetylene are used in steel mills, railroad shops, foundries and down to the smallest machine shop. Hydrogen likewise is in active demand; it is used more and more for cutting purposes and for light welding; it is also used for lead burning, platinum smelting, in the manufacture of filaments for electric lamps; and to a very great extent in the new industry of hardening oils by the hydrogenation process. This rapid development in the uses of two gases was facilitated by the introduction into this country of oxygen and hydrogen-generating apparatus several years ago. Large users of one or both of these gases were thus enabled to obtain their supply direct from their own generating plant at low cost, in a manner suitable to their individual requirements.

The International Oxygen Company of New York City, makers of the I. O. C. unit type generator, is bringing out a new style of oxygen and hydrogen generator under the name of the I. O. C. bipolar generator.

This type of generator resembles outwardly a filter press such as used in many chemical industries. Rene Moritz, of Wasquehal, France, patented this type of apparatus in the U. S. and elsewhere in 1913, and I. H. Levin, of the International Oxygen Company, who studied under Moritz and Flamand, perfected this machine greatly, and incorporated in it many novel and ingenious features.

Briefly described, the I. O. C. bipolar generator consists of a series of metallic plates (bipolar electrodes) clamped up together in a heavy frame, electrically insulated from one another, and separated by diaphragms of porous fabric. Each pair of these electrodes forms a closed cell divided by the diaphragm. These cells are filled with the electrolyte (caustic potash or soda solution).

An electric current admitted at one end plate passes on through the plates and the solution to the other end plate. In its passage it decomposes the water in the solution into the two gases—oxygen and hydrogen—which are released on opposite sides of each plate and emerge upward into the gas off-takes. The mingling of the oxygen and hydrogen in each cell or compartment is prevented by the diaphragm which, while permitting the passage of the fluid resists the passage of the gases.

As the gases are released and withdrawn water is automatically added from a supply tank. The operation is continuous so long as current and electrolyte are supplied.

In the smaller machines, the electrodes are carried on two steel rods supported on two heavy end pieces or pedestals of cast iron. In the larger generator the side rods are replaced by steel bars. The construction is one of extreme rigidity, absolutely proof against any distortion and consequent disarrangement of electrodes, with resultant leakage. It will be noted that there are only the two end supports—no middle support as in some types—simplifying the problem of erection and alignment.

The electrodes are clamped together by a heavy screw working in the rear support. A feature of special note in the I. O. C. generator is that a ball thrust bearing is interposed between the end of the clamping screw and the rear end plate—a refinement which contributes to the non-leaking qualities of the machine by doing away with the tendency of the electrodes to "ride up" from the side bars under screw pressure.

The electrodes are of a special patented design, the anode side being heavily nickeled, while the cathode side is of commercially pure iron. This use of two metals has an important bearing upon the efficiency of the generator, referred to more fully later. The surfaces of the electrodes carry vertical corrugations which are interrupted by a large number of repressions to facilitate the flow of electrolyte into the cell and the release of the gases from it.

At top and bottom of each electrode are two openings communicating by a cored channel with opposite sides of the plate. Those at the bottom are for the water intake and those at the top are for the gas off-take. It will be seen that each half of each cell (separated by the diaphragm) has its own independent water intake and gas outlet, so that there can be no possibility of the two gases mingling through these channels. Any gas leakage which may occur between the electrodes escapes to the open air and not into the adjacent cell or into the gas off-takes.

The diaphragms are of especially prepared asbestos fabric, of a thickness and texture carefully worked out by long experiment to give the best results. All around the edge of this fabric is molded a packing rim of pure rubber which rests in a recessed groove on the face of the electrode.

Obviously, in a generator of this kind, an essential of power economy is that all the current supplied the machine shall pass through the electrolyte and none

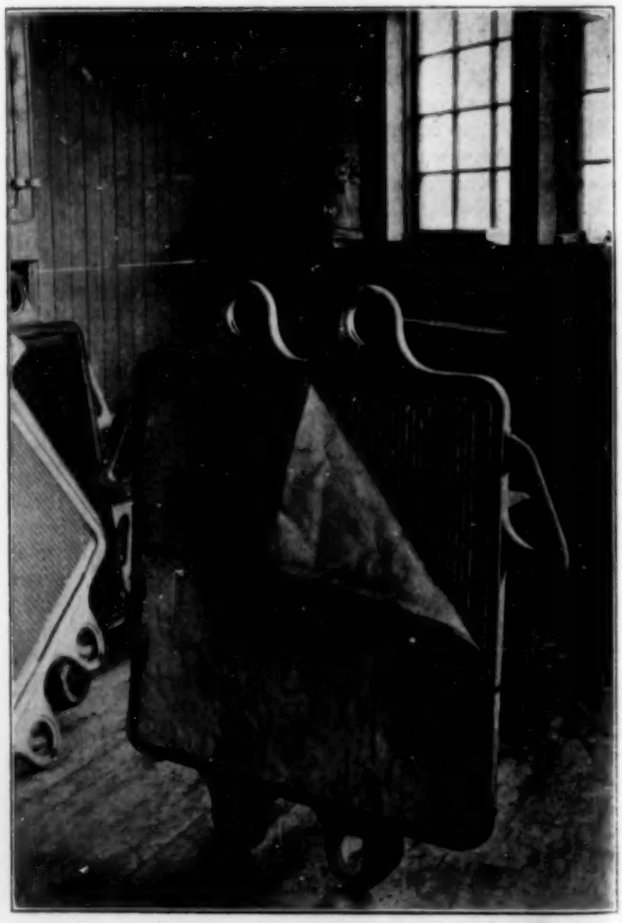


PLATE WITH DIAPHRAGM

of it be by-passed through the metal of the machine or through the water inlets and gas outlets.

In the I. O. C. bipolar generator the electrodes are insulated from the side bars of the frames by porcelain insulators resting on a wooden bar in the large machine and on fibre in the small machine. They are insulated from one another:—first, by the pure rubber packing rim surrounding the diaphragm; second, by nipples of pure rubber inserted in the water intake and gas off-take shoulders of the electrodes. These nipples, with everything clamped hoe, meeting one another and not only insulating the electrode shoulders but also providing an insulating tube in the interior of the water intakes and gas off-takes.

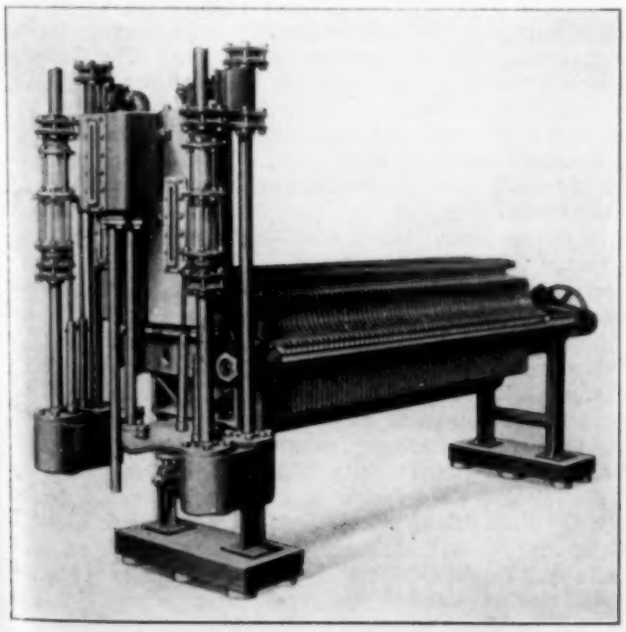
The gases rising from the electrodes and entering the gas off-takes, carry with them a small percentage of the electrolyte which, if allowed to enter the external piping system, would "ground" the apparatus and permit the escape of current.

To guard against this contingency, there is provided in the gas off-take system insulating pipe sections—each consisting of two sections of heavy glass tube clamped between iron flanges and so devised as to intercept and drain off through an insulating connection the moisture entrained in the gases. The gases go through these insulators substantially dry and free from electrolyte.

The voltage supplied to any electrolytic gas generator is utilized in two ways:—partly in decomposing the electrolyte; and partly in overcoming the internal resistance of the generator.

A number of features of the I. O. C. generator contribute toward high electrical efficiency. First of these is the use of the nickel anode and iron cathode (a patented combination) which has been found to materially facilitate the electrolysis or decomposition, by lowering the "over-voltage." Incidently, these bi-metallic electrodes prevent the formation of rust and oxides which would materially shorten the life of the apparatus.

A second feature in efficiency is the fact that the design of this generator is such as to retain within the apparatus most of the heat produced as a result of the ohmic resistance. This keeps the electrolyte and the electrodes at a comparatively high temperature which adds to the efficiency of the electrolytic process. Furthermore, the electrolyte used—a solution of caustic potash—has been found by experiment to utilize the current to best advantage.



I. O. C. BIPOLAR OXYGEN AND HYDROGEN GENERATOR. TYPE G

The generator is filled, on starting the apparatus, with the solution constituting the electrolyte. Obviously, as decomposition proceeds and gases are withdrawn, water must be supplied to the solution to maintain the right level and right density. On the front of the generator are two tanks or domes with glass water level indicators, which carry the solution. Pipes descend from these tanks to a water-feed manifold which branches into two pipes connecting independently to the two water intakes to the cells and also into two risers leading to the two independent gas domes above. Into these domes the oxygen and hydrogen are separately discharged as generated, the gas off-takes opening through an inverted U below the fluid level.

Next to these domes is a feed-water tank discharging distilled water through a float-controlled valve, as needed, to the solution tank on the front of the generator.

Arrangements are such that the proper fluid level is automatically maintained throughout the system. The two independent water intakes to either side of each electrode absolutely prevent any mingling of oxygen and hydrogen through the water supply.

This water-feed device creates an absolute balance of pressures throughout the generator, the vital importance of which will now be noted. Furthermore, it makes the water feed absolutely proportioned to, and under the control of, the rate of gas generation.

A primary essential in a generator of this type is to minimize circulation through the diaphragms—the function of these diaphragms being only to segregate the two gases as released at the same time permitting the passage of the electrolyte through their pores.

The two independent water supplies—one to either side of each diaphragm, but both under exactly the same pressure due to the hydrostatic head in the solution tank—obviously put the diaphragms under balanced fluid pressure, and eliminate circulation through them due to unequal pressures on their two sides.

This has two vital results. First, it removes any tendency to cause a mingling of gases through the diaphragm. Second, it relieves the diaphragm material from all mechanical stress and obviates any destructive erosive action which might be caused by solid particles in the electrolyte being forced through the fabric. This absolute balance and control of water pressure, then affects both the purity of the gases and the life of the apparatus.

The two gas off-takes discharge into the two independent gas domes already referred to, the gas emerging below the fluid surface through an inverted "U." It is apparent, then, that the pressure on both gases, clear back to the individual cells, is the same—being that determined by the hydrostatic head in the domes through the two independent risers from the water-feed manifold.

This balanced pressure in both gas off-takes prevents any mixture of the gases and contributes to the balancing of pressures on the diaphragms. It will be noted that gas and water pressures are predetermined and constant.

The gases, escaping from the gas off-takes rise through the fluid in the gas domes and pass out through discharge pipes at the top of the domes—thence downward to purgers in either side. These purgers are closed boxes of cast iron filled with water to a certain level. The gases except below the surface of this water, pass

upward through it, and emerge thence through the supply lines to the gas holders.

The function of these purgers is three-fold:—first, to catch any entrained fluid in the gas; second, to cool the gas; third, to act as a water-check-valve protecting the pressure system of the generator from any undue pressure of the gasholders.

A signal whistle is provided which gives notice when the level of the solution in the generator falls below the described limit. Glass sight-feed indicators on the solution tank and gas domes show the fluid levels and reveal the generation of the gases. Gauge glasses connecting with the electrodes at intervals along the generator show the fluid levels in the body of the apparatus.

To permit the emptying of solution from the generator when required, drain valves are provided. These are of the lever-operated gate type, designed to obviate any leakage or wear due to the presence of solid matter in the fluid.

To summarize, the notable features of the machine are:

First, the water feed to the generator is automatic and controlled entirely by the quantity of gas that the generator makes.

Second, the water feeds to the oxygen and hydrogen compartments are entirely independent, preventing mechanical transportation of the gases.

It is not to be inferred from this that the company recommends that these machines be started and then left absolutely to themselves. No mechanism is perfect—and the best apparatus made deserves a fair measure of consideration and attention. But it is claimed that the I. O. C. bipolar generator certainly calls for the minimum of attendance—at the most, only a small part of one man's time. And this feature contributes largely to the low cost of gas production to be realized by this apparatus.

New Uses of Monel Metal

Monel metal, the well-known alloy of approximately 68 per cent nickel, 1½ per cent iron and 30½ per cent copper, is finding its greatest uses and possibilities as an engineering alloy owing to its great strength and non-corrosive properties. The metal is commercially available in ingots, sheets, rods, castings, wire and a variety of other forms. The U. S. Government, through the Navy Department, has made tests which led them to specify it for outboard connections of battleships which would be rapidly corroded by sea water. Valves, valve seats and liners of cast Monel metal for pumps have been found very useful. Liners show no scoring, and after a short period of use assume a glass-like finish which reduces the packing to a minimum. The U. S. Navy requires all pumping equipment of ships be furnished with Monel metal.

IMMENSE VALVE FOR SUPERHEATED STEAM

In connection with very high steam pressures, where superheated steam is used, the alternate heating and cooling of bronze and steel valve seats cause them to become granular and crumble away. Monel metal has been given a severe test and found entirely satisfactory. A large valve of Monel metal weighing 3500 lb. is shown in the accompanying illustration. This valve was made by the Nelson Valve Company of Philadelphia for the Philadelphia Electric Company's new station, where the largest steam turbines in the world (30,000 and 35,000 kw.) are installed. This valve is made to withstand 250 lb. pressure and 800 deg. Fahr.

Monel metal castings have found a varied use where chemicals or other corroding agents must be handled, such as in washing apparatus; acid conductors, in refrigerating plants where the ammonia causes rapid corrosion; for pickling apparatus in connection with the rolling of steel sheets and tin plate. Several of the largest mills for rolling steel sheets have recently changed their entire equipment from iron to Monel metal. Among such plants may be mentioned the Illinois Steel Company, the West Penn Steel Company, and, most notably, the Vandergrift Plant of the American Sheet & Tin Plate Company, which is the largest rolling mill in the world.

Electric Power Development in the Pittsburgh-Wheeling District

The American Gas & Electric Company, 30 Church Street, New York City, owner of several operating plants throughout the Eastern and Central States, has purchased about 600 acres of land at Beech Bottom, or Windsor, W. Va., on the Ohio River, between Wellsburg and Wheeling, and is proceeding with the erection of a large electric power plant on a portion of this land.

This will be a wholesale plant; that is, it will supply power to the company's present plants at Wheeling, Canton, Newark, etc., and will also be in position to furnish power to other electric companies, street railways, manufacturers, etc.

The original installation will consist of two 30,000-kw. turbines, or a total of 60,000 kw. The plans, however, contemplate an ultimate capacity of 200,000 kw.

The plant is designed by Sargent & Lundy, Chicago. Contracts have been let to the Foundation Company, New York, for the installation of intake tunnels, building foundations and turbine foundations. The General Electric Company will furnish the turbines and Babcock & Wilcox Company the boilers. It is expected the plant will be ready for operation some time in 1916.

Contract has been made with a neighboring mine to supply the fuel requirements of the entire plant for the next forty-five years.

A double-circuit heavy steel line will be at once constructed to Canton and operated at 140,000 volts. Connection will also be made with the company's present system at Wheeling and Newark.

This new installation is expected to attract to the Pittsburgh district a number of industries to whom cheap electric power is an essential. It is planned to supply local business adjacent to the plant at 11,000 volts directly from their busbars, and it is the intention to invite consumers with high-load factors, such as chemical and steel furnaces, to locate near the power plant. With this in mind, the American Gas & Electric Company, in making their purchases of land, secured sufficient acreage to accommodate a number of such industries adjacent to the generators.

The statement is made by the company that the low price of coal in this district, the abundance of condensing water, low cost of disposal of ash, which will be

used to fill up lowlands, and the absence of high tax rates will make it possible to produce power at a cost which will enable them to sell it to consumers cheaper than it would be possible for the latter to manufacture it themselves.

Device for Reversing Open-Hearth Steel Furnaces

The Schumann device for reversing open-hearth steel furnaces, which is described in the following note, has been in continuous operation for the past seven months in a large steel plant in Maryland and has given full satisfaction. Its operation is shown in Fig. 1.

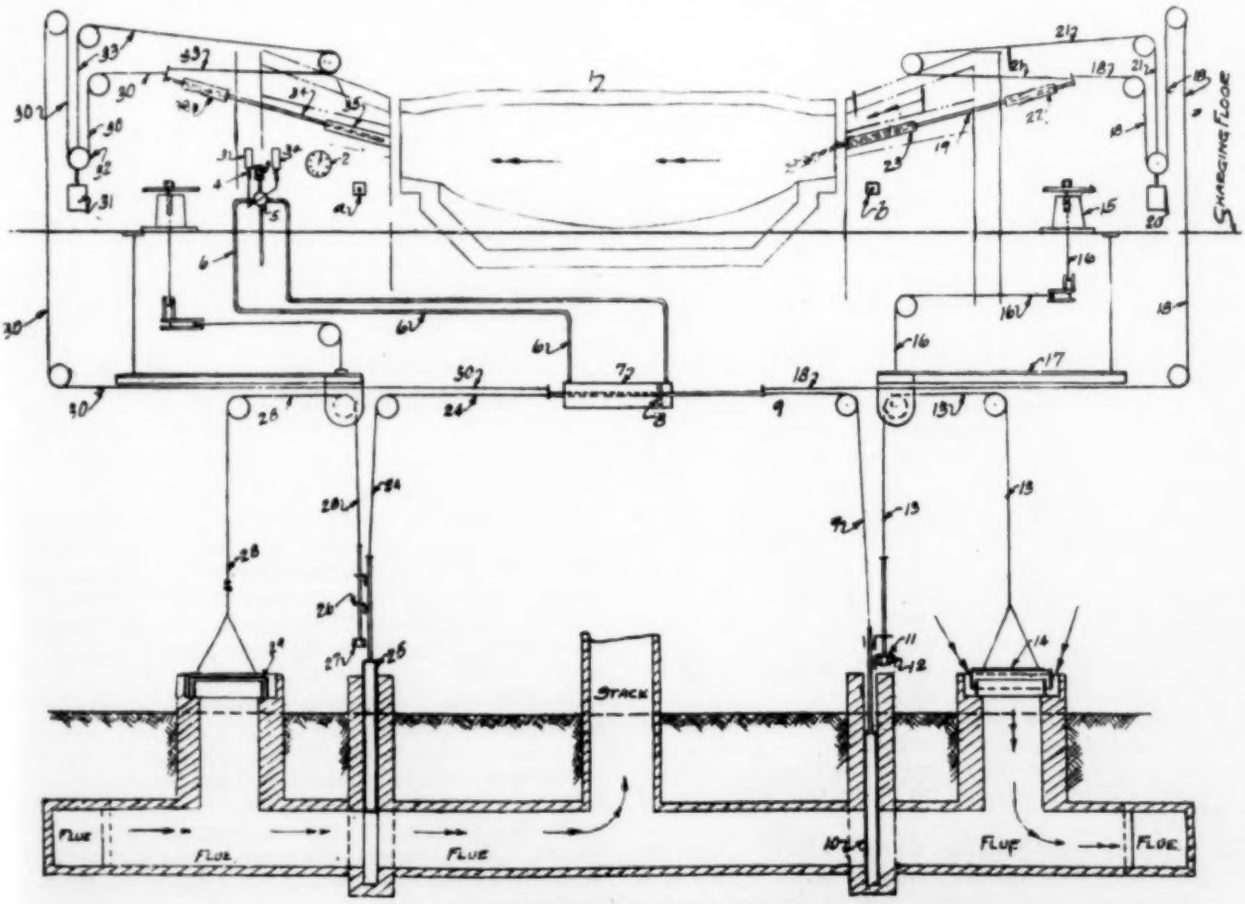
1 is the open-hearth furnace which is to be reversed every twenty minutes, 2 is a clock with hour hand forming a contact which operates the solenoid 3. The plunger 4 is thereby raised, opens the four-way valve 5, which controls the passage of air, water, etc., through the pipe 6. The air or water enters the cylinder 7 and pushes the piston 8, which slacks the cable 9, dropping the water-cooled damper 10 and shutting off the stack draft. When the water-cooled damper drops, the clamp 11 hits the nut 12, which raises the damper 14 by the pulling cable 13. This lets in the air, which goes to the checkers and then to the furnace. The damper lid can be adjusted, letting more or less air come in by the screw device 15.

When the piston 8 is over it will permit slack on the cable 17. When the cable 18 is slack the burner 19 will slide into the furnace and automatically starts operating. There is sufficient slack in the cable 18 so that the counterweight 20 will drop, pulling the cable 21, which pulls the burner 19 into the furnace. Cylinders 22 will open, letting on the steam and oil the moment the burner starts sliding into the furnace. Cooler 23 will protect the burner 19 when in and out of operation.

In case it is desired to reverse the furnace in less than twenty minutes, the button *a*, operating solenoid 3, is pressed. When the piston 8 is pulled over it has also pulled on the cable 24, which raises the water-cooled damper door 25, letting the stack draft pull on this end of the furnace. When the door 25 is raised up, the clamp 26 attached to it raises the nut 27, slackening the cable 28, which lets the damper lid 29 close, shutting off the air from the checkers. Piston 8, when pushed over, pulls on cable 30, which pulls the burner out of the furnace. Cable 30 raises the counterweight 31 and the sheave 32, which in turn slacks the cable 33 so that the burner 34 will come out of the furnace. The counterweight will then take up slack in cable 30, which is left over, so the burner 34 will remain out. When the burner 34 slides out it lays in cooler 35, which prevents it from being burnt up by flame from the opposite burner. When the burner starts sliding out of the furnace it ceases operating instantly, cylinder 36 shutting off the oil, steam or air.

When the furnace is ready to reverse twenty minutes later, the clock hand will touch the next contact point operating solenoid 3*a*, which opens the four-way valve and then operates everything in the opposite manner. If it is desired to reverse in less than twenty minutes, the button *b* is pressed. In case it is not desired to use the cable device to pull burners in and out of operation, a small slide valve can be used which lets the air, steam, water, etc., go to the small cylinders operating the burners in and out. When wanting to cool the furnace quickly for any particular reason, water-cooled dampers 10 and 25 are hung up, which will let the stack pull on the furnace from both ends.

This device is made by the Codd Tank & Specialty Company, Baltimore, Md.



SCHUMANN REVERSING DEVICE

Flotation Test Tank for Mill or Laboratory

In cyanidation it is considered safe and good practice to run pilot tests on the pulp parallel with the commercial treatment. In oil-flotation treatment the same rule should hold good. For this reason a small tank suitable for pilot-testing at operating commercial plants or in the laboratory has been designed by the Parral Tank System of Agitation, I. W. Hellman Building, Los Angeles, Cal. Although the apparatus and the principles of operation are patented, the free use of this tank is offered to any one for testing purposes.

Fig. 1 shows the dimensions of this tank and the operating apparatus embodied in its construction from which the tank may be made at any works. If the air pressure available for use is found too high, a short rubber or canvas sleeve may be slipped over the discharge orifice of the transfer pipes and directed downward in the tank charge.

The various parts of the tank and apparatus are lettered in the drawing as follows:

AA is the line through plan view of top of tank on which the vertical elevation is drawn.

a are transfer pipes through which the pulp is continuously drawn from the bottom and spouted 2 in. underneath top of tank charge.

b is the arm from which the skimming paddles *c* are suspended.

c are skimming paddles (pieces of rubber belt), 8 in. x 8 in., attached to, but swinging loosely on, the arm *b* by strap hinges *d*.

d are the strap hinges referred to under *c*.

e is an iron hoop around the top of the tank, but ¼ in. above it, to furnish a rest on which the arm *b* slides.

f is a pin fastened through the center of the arm *b*, which drops into a hole bored in the wooden filler *F*, the center of rotation for the arm.

F is the wooden filler in center of the tank to occupy space and reduce the holding capacity of pulp, thereby obviating the necessity of fine grinding a larger sample of dry pulp.

g is a handle on the arm *b* by which the arm is revolved by hand to skim off the mineral-laden froth.

h is a baffle-board to intercept the flow of froth around in the mixing circle and deflect it outside into the box *o*.

i are eye-bolts by which transfer pipes *a* are fastened in place.

j is the reducer fitting at the intake end of the transfer pipes *a*.

k is a compressed-air pipe nozzle through which the compressed air is introduced into the transfer pipes.

l is the iron flange into which the compressed-air nozzle *k* is screwed.

m are lag screws which fasten the filler *F* to the bottom of the tank so as to give it a central position in the tank.

n is the iron handle for the wooden plug in the outlet pipe *p*, by which this plug is placed or removed.

o is the receiving box for mineral-laden froth.

p is the pipe through which mineral-laden froth is discharged.

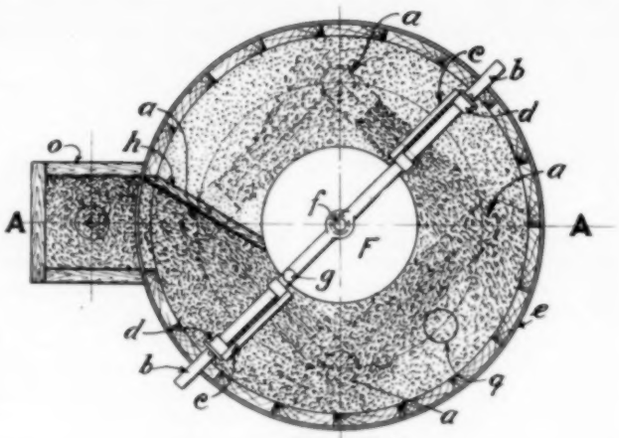
q is an outlet in the bottom of the tank through which the treated pulp is discharged.

r is the pulp level of the charge to be treated.

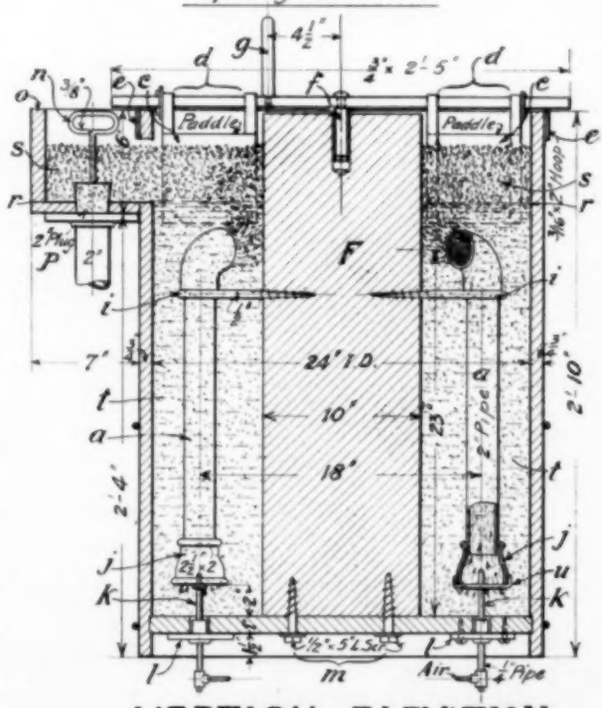
s is the layer of mineral-laden froth formed on top of the pulp.

t is the pulp-filled "mixing circle," within which the pulp is kept in agitation and in which the froth is created and rises mineral-laden to the surface.

u is a small iron strap clamped across the bottom opening of the reducer *j*, through the center of which the air nozzle *k* enters and is held in place.



PARRAL EXPERIMENTAL TANK
OIL FLOTATION
Capacity 100 lbs. in 3:1



In the laboratory, or at a commercially operating plant, this experimental tank is set on rack or trestle about 18 in. above the floor for convenience in making bottom connections and drawing off the charge.

The adaptation of Parral tanks for oil flotation in commercial operation is the subject of a pamphlet recently issued by the Parral System of Tank Agitation (Mr. Bernard MacDonald, manager), I. W. Hellman Building, Los Angeles, Cal.

Selenium.—The demand for selenium in 1915 fell off considerably, owing to absence of buying orders for railroad signal lamps and the curtailment of foreign export. The copper refineries have decreased their production somewhat, and in some cases the method of production has been changed. The price has ranged from $2 to $5 per pound.

Industrial Notes

Hearing on Dyestuffs Tariff.—Chairman Kitchen announced on Jan. 10 that the House Ways and Means Committee would begin hearings Jan. 14 on Representative Hill's bill proposing protective import duties on dyestuffs and certain chemicals, with a view to protecting and building up a domestic dyestuff industry.

Messrs. **Eimer and Amend** will erect a new building adjoining their present one at Eighteenth Street and Third Avenue, New York, to take care of their increasing business.

The **Supplee-Biddle Hardware Company,** Philadelphia, Pa., has increased the capacity of its Monel metal-casting foundry, to take care of its increased business.

The Wilson-Maeulen Company of New York, pyrometer manufacturers, have moved to their new factory at Wales Avenue and East 142nd Street. The office and laboratory are also at the new address.

The H. W. Caldwell & Son Co. of Chicago announces the opening, on Jan. 1, 1916, of a sales and engineering office at 711 Main Street, Dallas, Tex., in charge of Mr. J. C. Van Arsdell.

The **Edison Portland Cement Company,** whose factory is at Stewartville, N. J., will resume operations in the spring. New machinery and improvements to cost $200,000 have been authorized and will be completed by that time.

Disc Crushers.—Chalmers & Williams of Chicago Heights, Ill., have furnished one 48-in. Symons disc crusher to the Nevada Consolidated Copper Co. and one to the American Smelting & Refining Company at Hayden, Arizona.

The Armstrong Cork Company of Pittsburgh, Pa., has issued another edition of their corkboard catalog entitled "Nonpareil Corkboard Insulation." This book contains much information of value to anyone interested in heat insulating materials for low and moderate temperatures.

Duriron.—The Duriron Castings Co. of New York City has sent us a very attractive little concentrating dish, made of acid-proof duriron, which may be used as an ash receiver, but on the desk of chemical and metallurgical engineers will undoubtedly excite the curiosity of the owner to try it out as to the claims made for the non-corrosibility of duriron under trying conditions.

The new plant of the **Federal Dyestuff & Chemical Co.** at Kingsport, Tenn., is being pushed to completion as rapidly as possible. A site of 200 acres was donated by the Kingsport Development Co.

The November number of **The Labor Saver,** the little booklet issued by the Stephens-Adamson Mfg. Co. of Aurora, Ill., contains some interesting illustrated descriptions of coal handling machinery.

The Wellman-Seaver-Morgan Company, Cleveland, Ohio, has received contracts for four gas producers, together with a producer building and coal and ash-handling machinery for the Imperial Steel Works of Japan.

An Industrial Exposition will be held in Dayton, Ohio, Jan. 14 to 22, 1916. The exhibit will be held in the excellent new Delco building of the Dayton Engineering Laboratories Company. There will be ten exhibits, including automobiles, machinery, building materials, electricity, flowers, food, mercantile, advertising, business appliances and municipal shows. The object is to display goods made in Dayton.

Increasing Use of Aluminium.—The Nordyke & Marmon Co. of Indianapolis created a sensation at the recent Automobile Show in New York by showing a car with engine cylinders and crank case cast integral in one light, sturdy block of aluminum. Aluminum pistons are also used. The extensive use of aluminum castings in this car has resulted in a reduction of weight by 1000 lb.

Substitution of Copper for Aluminium.—Some companies have found it profitable to substitute copper wire for aluminum conductors in their transmission lines, in view of the high price which can be obtained for the aluminum.

Aluminium and Bauxite—Information on the aluminium industry of the United States in 1914 is contained in Bulletin No. 7, Part 1, of the Mineral Resources of the United States. Production statistics, consumption, imports, uses and methods of manufacture are included. The author is Mr. W. C. Phalen.

The Donora zinc plant of the American Steel & Wire Co. commenced producing sulphuric acid on Dec. 23. When the entire plant is completed it will contain ten furnaces with an output of 40,000 tons of spelter and 100,000 tons of commercial sulphuric acid per year. The acid plant is a three-unit plant, each unit comprising a tower, chamber and two roasting furnaces.

The Davison Chemical Corporation has been organized to take over all of the assets of the Davison Chemical Company of Baltimore, Md., large makers of sulphuric acid and fertilizer. Additions to the plant are being made which will give it an output of 300,000 tons of acid per annum. An acidulating plant is also under construction which will have a capacity of 300,000 tons of acid phosphate per annum. It is expected that this plant will be completed by the middle of next summer.

The **Morse Bros. Machinery & Supply Co.** have purchased the entire plant of the Kuenzel Process Smelter located at Buena Vista, Colo., and will dismantle and ship to Denver. This plant was never completed and only parts of it were in operation at all. A complete power plant of high pressure boilers, engines, blowers, compressors, crushing plant, machine shop. Fire and boiler feed pumps, shafting elevators, etc.

The **Mineral Products Corporation,** which started at the end of 1915 the successful production of potash from Utah alunite, is so much pleased with the results so far obtained that it intends to double the capacity of its Marysville plant in the near future. It is expected that the contract for this extension will be let to Westinghouse, Church, Kerr & Co. Mr. Howard F. Chappell is the president of the company. The vice-presidents are Mr. C. H. Macdowell, representing the Armour interests, and Mr. S. J. Jennings, representing the United States Smelting Co., while Mr. R. B. Forsythe is general manager of the mine and the plant.

The **Buffalo Potash and Cement Corporation** has been formed to erect a plant with a capacity of 20 tons of potassium salts per day with a simultaneous daily production of 750 barrels of cement. It is expected that the first unit of the plant, producing 10 tons of potassium salts per day, will be in operation in April, 1916. The Ruggles-Coles Engineering Company has undertaken the construction of the plant and supervision of installation. Mr. William B. Ruggles is a member of the board of directors of the Buffalo Potash & Cement Corporation.

To Authorize Exploration.—A bill designed to authorize exploration for coal, phosphate, oil, gas, potassium and sodium in public lands, and to provide for its disposition, will come before the House this week. The bill is a committee measure.

Mineral Production.—The value of the mineral production of the United States in 1914, according to the

Geological Survey, was $2,114,946,024, being exceeded only by 1913 and 1912.

Sulphuric Acid in 1915.—The estimated production for 1915 of 50, 60 and 66-deg. acid is 4,007,000 tons, expressed in terms of 50-deg. strength, according to the Geological Survey. In addition there was a production of nearly 49,000 tons of fuming acid and oleum. These figures include by-product acid produced at copper and zinc smelters amounting to 952,000 tons of 60-deg. acid. This is an increase of 25 per cent over 1914. The prices were much higher than in 1914, and consequently the total value will be far in excess of the previous year.

Large Petroleum Production in 1915.—According to the Geological Survey the marketed production of petroleum in the United States in 1915 approximated 267,400,000 barrels, and the total yield approximated 291,400,000 barrels, about 24,000,000 barrels being placed in field storage. The increase is accounted for by the continued output of oil in large quantities from Oklahoma, Texas and Louisiana.

Increased Arsenic Production.—The estimated production of white arsenic for the year 1915, according to the Geological Survey, was 5,195 tons (of 2000 lb.), with a value at the smelter of 2 cents a pound. The estimate is based on the known production for the first ten months and the probable output for November and December. This output is an increase of more than 11 per cent over the 1914 production and 65 per cent over the 1913 production. The demand is far below the possible production, which could probably be made three or four times the present output if prices were sufficiently high.

Transvaal Gold Production.—The number of companies reporting to the Transvaal Chamber of Mines in August, 1915, was 63. The total quantity of ore milled during that period was 2,478,267 tons. There were 9955 stamps in operation, with an average duty of 9.42 tons per 24 hr. Tube-mills in commission numbered 321. The yield for the month was 778,763 fine ounces gold. The tonnage treated and the yield of fine gold are the largest recorded this year.

Iron and Steel in Canada.—Bulletin 349 has been issued by the Department of Mines, Canada, containing information on Canadian production of iron and steel in 1914.

Electrothermic Smelting of Iron Ores in Sweden is the title of an illustrated bulletin, No. 344, just issued by Dr. Alfred Stansfield for the Canadian Department of Mines, Ottawa, Canada.

Copper in Arizona.—Market conditions resulting from the European war lessened the output of copper in Arizona from 407,923,402 lb. in 1913 to 393,017,400 lb. in 1914, according to the U. S. Geological Survey. Nevertheless, Arizona continued to be the leading copper-producing State.

Coal Mining in Illinois—The growth of the industry in this State, the development of methods of mining and the present mining practice and markets are given in Bulletin 13, published by the Illinois Coal Mining Investigations, Urbana, Ill. The author is Mr. S. O. Andros.

Platinum in Spain.—The discovery of platinum in Spain was announced in an address made by Professor Orueta before the Society of Civil Engineers of Spain. Professor Orueta made an examination of the Ronda Mountain for the Institute Geologico (Geological Society) and found rich and extensive deposits. A Royal Decree has been announced reserving this district within certain boundaries to the State for a limited period for scientific investigation.

Mineral Resources of California.—The California State Mining Bureau is preparing a new general report of all of the mineral resources of California, under the direction of State Mineralogist Fletcher Hamilton. Instead of delaying publication until the entire area of the State has been covered the reports are being issued as advance chapters, by groups of adjacent counties, as soon as complete by the field men. All mines, quarries, mineral springs, cement mills and other plants handling mineral products are listed and described. The chapters already issued may be obtained upon application to the State Mining Bureau, Ferry Building, San Francisco.

Hydroelectric Development and Nitrogen.—In a talk recently given before the Commercial Club of Boise, Idaho, Mr. Henry J. Pierce of Seattle, Wash., said that the United States imported during 1913, about 625,000 tons of Chilean nitrate, valued at $21,000,000, upon which the Chilean export duty was 60 per cent. The United States thus paid to the Chilean government $12,600,000, which may be considered merely a part of the amount which the people of the United States pay for its policy of water-power stagnation. In other words, the people of this country would be quite as well off as they now are if they granted a subsidy or bonus of $12,600,000 per annum for the establishment of the water-power nitrogen industry in the United States. In Europe over 1,200,000 water-hp. is used.

Obituary

Richard Henry Lee, superintendent of the Lebanon blast furnaces of the Pennsylvania Steel Company, died suddenly on Dec. 8, 1915. Mr. Lee received his education at Lehigh University, and upon leaving there was placed in charge of the cold blast charcoal furnaces of the Logan Iron & Steel Company at Burnham and Greenwood Furnace, Pa. He became general superintendent of the Logan company in 1891, and was assistant general superintendent of the Colorado Fuel & Iron Company from 1899-1903. He was connected with a number of other companies, and in 1906 became associated with the Pennsylvania Steel Company, taking charge of the Lebanon furnaces. Mr. Lee was also consulting engineer for the American Manganese Manufacturing Company in 1914-1915. He was noted for giving freely to others the benefit of his technical knowledge, and he was a frequent contributor to the American Institute of Mining Engineers and to the technical press. His last contribution to technical literature was published in the issue of Dec. 1, 1915, of METALLURGICAL AND CHEMICAL ENGINEERING (page 882), when he discussed the use of wet ores in charcoal blast furnaces. He made many warm friends in his numerous positions. He was a member of the American Iron and Steel Institute, the American Institute of Mining Engineers, and the Engineers' Society of Western Pennsylvania.

T. L. Willson, who took a prominent part in the early development of the calcium-carbide industry, is dead at New York City. Mr. Willson began his engineering work in 1880, when he constructed an arc outfit used for street lighting at Hamilton Ont., Canada. While the principal work which led to the foundation of the calcium-carbide industry, and in which he very actively participated, was done in North Carolina, Mr. Willson lived later many years in Canada and was interested in many undertakings besides calcium-carbide and acetylene. Until two years ago Mr. Willson was president of the International Marine Signal Company. Since that time he had devoted his entire attention to a new process for producing nitrogenous fertilizers from the air.

Personal

Mr. **Edgar Baruch,** chairman of the Southern California Section of the American Chemical Society, was re-elected a director of the Chamber of Mines and Oil of Los Angeles, Cal., at the annual meeting on Dec. 16.

Mr. **Charles A. Chase** has moved his Denver office from the First National Bank Building to 812 Cooper Building.

Prof. **G. H. Clevenger** of Leland Stanford, Jr., University attended the Pan-American Congress in Washington, and before his return to the Pacific Coast he was a few days in New York City.

Mr. **E. H. Hamilton,** formerly manager of the Virginia Smelting Co., has become consulting metallurgist to the Consolidated Mining and Smelting Co., Ltd.

Mr. **Elwood Hendrick,** who will be remembered as secretary and manager of the Albany Aniline and Chemical Works back in the early eighties, but more recently as editor of *The Percolator* and as vice-president of the Chemists' Club for several years, has left Wall Street. He has retired from his connection with Messrs. Denny, Pomroy & Co. of the New York Stock Exchange, with a view to addressing himself to literary work. We are very glad, indeed, to state that Mr. Hendrick has accepted the invitation to become a regular contributor to this journal.

Mr. **James M. Hyde** expects to move from San Francisco to Denver within a month, and make his future headquarters in the latter city.

Mr. **R. E. Howe,** formerly chief chemist for the Anaconda Copper Mining Co., has been promoted to be assistant superintendent of the converter department. He is succeeded by the former assistant chemist, **Pierce Barker.**

Dr. **R. A. Kocher,** chief chemist of the Pacific Chemical Wood Products Co. of San Francisco, was recently in New York City and the Eastern cities.

Mr. **J. H. Mackenzie** will become president of the Alaska-Treadwell on Jan. 1. He will be succeeded as consulting engineer by **P. R. Bradley,** who has been general superintendent. The latter position will now be filled by **Russell Wayland.**

Mr. **Stuart B. Marshall,** who has been connected with the Dunbar Furnace Company for 21 years, has severed his connection with that company to take charge of the property of the Aluminum Company of America at Whitney, N. C. This plant was recently acquired from the Southern Aluminum Co. and the works and immense dams are being completed. A new town, to be called Badin, is also under construction.

Mr. **Thomas C. Oliver,** manager of the Chemical Construction Co., Charlotte, N. C., was married on Jan. 5 to Miss Catherine Hill of Austin, Tex. Mr. Oliver spent some years as a mining engineer in the West before becoming associated with the Chemical Construction Co.

Mr. **Thomas T. Read,** who a few years ago, as the New York editorial representative of the *Mining Press* and as the very active secretary of the New York Section of the American Institute of Mining Engineers, made many friends in New York, has joined the staff of the New Jersey Zinc Co. in New York City.

Mr. **R. W. Schultz,** who as mill superintendent for the Mond Nickel Co., Ltd., of Conniston, Ontario, has had charge of extensive experimenting in the concentration of the copper-nickel ores of the Sudbury district, has resigned, having completed this work with entire success. He is spending several weeks at his home in Ravenna, Ohio.

Mr. **B. B. Thayer** expects to sail for Chile about Jan. 15, where he will spend about a month.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

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Aqueous Bath Apparatus

(Continued)

384,806, June 19, 1888, William W. White of Waterbury, Conn., assignor to Rogers & Brothers of same place.

Relates to a rack for supporting such articles as spoons, forks, etc., that are subjected to unequal wear, and require extra thick deposits on certain spots. The rack consists of two parallel rods suitably supported, and a third rod rotatable about its longitudinal axis, the third rod is supported upon the supports of the first rods. The third rod is provided with a plurality of spaced transverse flat wire springs the ends of which are connected by a chain. The third rod with springs and chain are folded back, the spoons, etc., placed across the first parallel rods so as to lie between the flat springs, the third rod and springs are then folded down and secured so that the chain engages and holds each spoon, etc., in place, and the frame supported over the plating tank so that the spots to be plated extra heavy will receive the desired deposit. The spoons, etc., are then removed and plated entirely. Or the plating process may be reversed, the spot plating being applied last.

414,860, Nov. 12, 1889, William A. Dunlap of Pittsburgh, Pa.

Relates to racks for supporting articles to be electroplated. The rack consists of a clamp made of a continuous rod or stiff wire, bent U-shape with preferably a coil at the bend. The long parallel arms are provided with a plurality of transverse rods projecting toward each other, which support an article to be plated. The arms are held together by a link or clasp. It is especially designed for such articles as screw-threaded caps for tin boxes.

441,892, Dec. 2, 1890, William J. Possons of Cleveland, Ohio, assignor to The Brush Electric Company of same place.

Relates to clamps for holding arc light carbons while being electroplated. The clamp may be described as a tubular clamp divided longitudinally into two parts which are hinged together, and which are provided with a spring to force the jaws into engagement with the carbon. The clamp is provided with an insulated metal contact and contact spring which electrically cuts out a clamp when not supporting a carbon, thereby preventing an open circuit among carbons which are connected in series. The patent refers to a copending application which became patent No. 441,894.

441,894, Dec. 2, 1890, William J. Possons of Cleveland, Ohio, assignor to The Brush Electric Company of same place.

Relates to an apparatus for distributing, supporting and electroplating a large number of arc light carbons at one operation. The carbons are quickly sorted on a subdivided tray, which upon inverting, discharges the carbons into a bank of tubular holders, the latter being quickly filled. A plurality of carbon clamps, such as described in his patent 441,892, are mounted upon a support, and placed over the projecting ends of the carbons in the bank of tubular holders, whereby the carbons are taken up by the clamps. The clamped carbons are next immersed in a tray of separate electrolytic cells wherein they are electroplated. The patent should be consulted for details.

459,838, Sept. 22, 1891, Edward S. Hayden of Waterbury, Conn.

Relates to a siphon to automatically maintain the level of the electrolyte in a tank, constant. It consists of a U-tube having one arm longer than the other, and an opening in the outer wall of the bend opposite the short arm. The siphon is secured in the side wall of the tank, with the long arm outside, in such a manner that the small opening is below the top of the tank. If the tank became too full, the excess liquid would cover the small hole, and the siphon would thereupon automatically remove the excess solution. After the hole became uncovered, the siphon would act as an overflow spout until the level of the solution reached that of the lower wall of the bend.

469,538, Feb. 23, 1892, Alexander D. Buchanan of Long Island City, N. Y.

Relates to a process of and apparatus for electroplating the iron hulls of vessels. The vessel is floated into a dock and over a collapsible flexible envelop which has been dropped to the floor of the dock. The vessel is supported upon a suitable keel-base, and by side braces, and is then thoroughly cleaned by scratch brushes, etc. A pickle of weak acid is then supplied to the flexible envelop which is raised to surround the ship, and the cleaning process completed. The pickle is then withdrawn and an alkaline copper plating solution supplied to the envelop, the iron hull being connected as cathode, and using an anode of copper links connected together, each link supporting one or more large insulating washers. As the level of the electrolyte in the envelop is raised, workmen scrape the iron just above the level to insure a deposit of copper taking place. After a deposit with alkaline electrolyte has been effected the ordinary copper sulphate bath is substituted.

479,557, July 26, 1892, Edward A. Clark of Boston, Mass.

Is for a toy consisting of a small electroplating outfit, made up of two small cells of battery in a case, the latter supporting a cell for the electrolyte. Binding posts are connected to the battery, to which wires for the anode and cathode may be connected.

496,597, May 2, 1893, Seth C. Catlin of Bloomfield, N. J., assignor to Emma F. Catlin of same place.

Relates to an apparatus for supporting articles to be electroplated, and consists of two wooden frames hinged together, preferably with rawhide, each frame being covered with a layer of muslin or canvas, so that the articles to be plated are inclosed therein. A number of hooks within each frame electrically connected to outer suspension hooks, provide means to support the articles.

497,129, May 9, 1893, Albert Roper Reams of Elmira, Cal.

Relates to a cabinet for holding the electroplating battery, various electrolytes and cleaning solutions, also a lamp or other heating apparatus to suitably heat the necessary liquids. The zinc of the battery is suspended from a pulley and may be raised or lowered as desired to vary the current strength.

498,707, May 30, 1893, Thomas S. Crane of East Orange, N. J.

Relates to an apparatus for coating the iron hulls of vessels, and consists of detachable open-sided flat receptacles for holding the electrolyte, the receptacles being held to the sides of the ship by suitable frames which in turn are held in any desired place by electromagnets. The hull of the ship is electroplated in sections, the joints of the several sections overlapping. The patent should be consulted for details.

501,996, July 25, 1893, Stephen H. Emmens of London, England.

Relates to an apparatus for electro-refining pig iron, and consists of a lead-lined steel tank, in which are placed insulating linings of ebonite, etc., the linings providing receptacles at the bottom to collect anode slimes and cathode powder or flakes. As anodes, the ordinary bars of pig iron, as produced by the foundries, are used. These are suspended by hooks from notched anode bus-bars above the cells on each side. The cathodes consist of a plurality of bars of malleable iron. The electrolyte is a nearly saturated solution of ammonium sulphate, covered with a layer of paraffin oil to prevent oxidation. A voltage of from three to four volts is used, and a current of about one-twentieth of an ampere per square inch of active cathode surface.

Book Reviews

Experimental Organic Chemistry. By **James F. Norris,** Ph.D. 5½x8 in., 215 pages; price, $1.25 net. New York and London: McGraw-Hill Book Co., Inc.

A skillfully written laboratory guide, which ought to enthuse as well as instruct the student. The directions, cautions and precautions, are minute and accompanied by the reasons—a most gratifying style of scientific writing intended for the instruction of students. The tests and experiments chosen are mostly those concerned with very common organic materials, such as fats, soaps, starches, sugars, etc., and thus the interest of the student is most securely held. The book is admirably conceived and executed.

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Elementary Electricity and Magnetism. By **Wm. S. Franklin** and **Barry MacNutt.** 176 pages, 152 illus. Price $1.25, New York. The Macmillan Company.

This is an elementary work on the fundamental phenomena in electricity and magnetism, presented from the standpoint of electromechanics, and thus concerned more particularly with results than the exact nature of the physical causes. The five chapters deal respectively with the magnetic effects of electric currents, chemical effects of electric currents, heating effects, induced e.m.f., and electric charges and condensers; appended to each chapter are several practical problems, with answers.

This book is essentially for the beginner and is made interesting by frequent happy allusions to the practical or useful aspects of the phenomena described, which are very clearly presented.

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Food Analysis. Typical Methods and the Interpretation of Results. By **A. G. Woodman.** 8 x 5½ in., x + 510 pages, 107 illustrations. Price, $3.00 net. New York: McGraw-Hill Book Co., Inc.

One of the books of the International Chemical Series, edited by Professor Talbot of the Massachusetts Institute of Technology, this is written by the associate professor of food analysis at that institution. It is intended for students' use, certain typical foods being selected for analysis, more because of the methods of analysis which they illustrate than because of economic importance. The book is, therefore, not a complete compendium of specific methods of analysis of every important food. Particular emphasis is laid on the interpretation of the analyses so as to judge of the practical values of the foods tested. Three general chapters treat of methods of manipulation, use of the microscope, examination for food colors and preservatives; after these milk, oil, butter, etc., are taken up in separate chapters. It is a practical and valuable book. The fine quality of paper used by the printers is especially commendable, over 500 pages (270 sheets) being only three-quarters of an inch thick, and yet of excellent opacity.